NATIONAL LABORATORIES: WORLD-LEADING INNOVATION IN SCIENCE

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

MARCH 14, 2018

Serial No. 115–52

Printed for the use of the Committee on Science, Space, and Technology

Available via the World Wide Web: http://science.house.gov

U.S. GOVERNMENT PUBLISHING OFFICE

29–779PDF WASHINGTON : 2018

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NATIONAL LABORATORIES: WORLD-LEADING INNOVATION IN SCIENCE

WEDNESDAY, MARCH 14, 2018

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Committee met, pursuant to call, at 10:03 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Lamar Smith [Chairman of the Committee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Full Committee

National Laboratories: World-Leading Innovation in Science

Wednesday, March 14, 2018
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Mark Peters, Director, Idaho National Laboratory

Dr. Susan Seestrom, Advanced Science and Technology Associate Laboratory Director and Chief Research Officer, Sandia National Laboratory

Dr. Mary E. Maxon, Associate Laboratory Director for Biosciences, Lawrence Berkeley National Laboratory

Dr. Chi-Chang Kao, Director, Stanford Linear Accelerator Center, National Accelerator Laboratory

Dr. Paul Kearns, Director, Argonne National Laboratory

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

Wednesday, March 14, 2018

TO: Members, Committee on Science, Space, and Technology

FROM: Majority Staff, Committee on Science, Space, and Technology

SUBJECT: Full committee hearing: "National Laboratories: World-Leading Innovation in Science"

The Committee on Science, Space, and Technology will hold a hearing titled *National Laboratories: World-Leading Innovation in Science* on Wednesday, March 14, 2018, at 10:00 a.m. in Room 2318 of the Rayburn House Office Building.

Hearing Purpose:

The purpose of this hearing is to review the current objectives and programs carried out by the Department of Energy (DOE)'s national laboratories. The hearing will examine the broad scope of innovative basic science, early-stage applied research, mission-focused technological development, and national security work performed at DOE laboratories. This hearing will also examine the impact of DOE funding and priorities on laboratory research, and will allow the national laboratory directors to provide insight to the Committee on the most effective way to manage the DOE laboratory system.

Witness List

- **Dr. Mark Peters,** Director, Idaho National Laboratory
- **Dr. Susan Seestrom,** Advanced Science and Technology Associate Laboratory Director and Chief Research Officer, Sandia National Laboratory
- **Dr. Mary E. Maxon**, Associate Laboratory Director for Biosciences, Lawrence Berkeley National Laboratory
- **Dr. Chi-Chang Kao**, Director, Stanford Linear Accelerator Center, National Accelerator Laboratory
- **Dr. Paul Kearns,** Director, Argonne National Laboratory

Staff Contact

For questions related to the hearing, please contact Jimmy Ward of the Majority Staff at 202-225-0222.

Chairman SMITH. The Committee on Science, Space, and Technology will come to order.

Without objection, the Chair is authorized to declare recesses of the Committee at any time.

And welcome to today's hearing entitled "National Laboratories: World-Leading Innovation in Science."

And I'll recognize myself for an opening statement.

Today, we welcome a diverse group of Directors from five of DOE's national laboratories. They oversee innovative work in basic science and early-stage research performed daily by some of the best scientists and researchers in the world.

Our witnesses represent national labs that fulfill the Department of Energy's missions within the Office of Science, applied energy and national security programs. The Science Committee's jurisdiction over the DOE budget includes over $9 billion for civilian research, development, demonstration, and commercial application programs, much of which is conducted by the national labs. Over the past 70 years, this research community has led to monumental achievements in medicine, manufacturing, computing, and energy technology development.

The labs that are represented here today have made invaluable contributions to U.S. scientific progress and leadership. They have repeatedly demonstrated that basic science research is the most effective way to encourage innovation in technology.

In 1942, a group of scientists in Chicago created the first nuclear reactor. Four years later, Argonne National Laboratory was formed to continue this groundbreaking nuclear research. Using the lab's expertise in materials and nuclear science, Argonne designed the nuclear reactor used in the USS Nautilus, the first nuclear-powered submarine. These reactor designs also became the prototype for most of today's commercial nuclear power plants. The impact of Argonne's research is far beyond what the early nuclear scientists could have imagined.

In the 1960s, SLAC National Accelerator Laboratory conducted its first groundbreaking experiments in particle physics using the first linear particle accelerator. This research led to the discovery of quarks, elementary particles that are the fundamental components of matter. Their discovery has changed the way we understand our universe at the most fundamental level. SLAC has led the world in linear accelerator technology for decades, expanding its focus from particle physics to include materials science, alternative energy research, biology, and cosmology.

Although Sandia is one of the Department's four nuclear weapons labs, the lab's expertise in science and engineering has broad applications across our economy. In the 1980s, Sandia National Lab collaborated with industry to develop the primary drill bit used in horizontal drilling. Sandia's basic research in geology led to the development of microseismic fracture mapping techniques for hydraulic fracturing. Industry partners adapted these techniques for commercial use and deployed technology to maximize energy production across the country.

At Lawrence Berkeley National Laboratory, a large multipurpose science lab, researchers have discovered 16 different elements, fabricated the world's smallest synthetic motor, sequenced part of the human genome, and discovered dark energy through the Supernova Cosmology Project. Scientists at Berkeley Lab also developed the genetic engineering technology known as CRISPR, which could one day allow scientists to remove cancerous genes.

Finally, Idaho National Laboratory is the Nation's premier nuclear technology laboratory. INL scientists have designed and constructed 52 nuclear reactors, including the first reactor to generate electricity in 1951. Today, INL's nuclear expertise supports the military's naval propulsion system, the civilian nuclear power industry, and develops tools to detect hidden nuclear material around the world.

DOE user facilities provide our nation's researchers with the most advanced tools of modern science, including particle accelerators, light sources, and supercomputers. Approximately 32,000 researchers each year from academia and the private sector use DOE facilities to perform new scientific research and develop new technologies.

Last month, the House passed three bipartisan Science Committee infrastructure bills that authorize DOE funds for critical upgrades to a number of high-priority national lab user facilities. In fact, user facilities from four of the five labs represented here today are included in those pieces of legislation. We look forward to hearing from our witnesses about the potential impact of these upgrades.

It is a central goal of this Committee to ensure that our national labs remain the best in the world. To maintain our competitive advantage as a world leader in science, we must continue to support the research that will lead to next-generation energy technologies.

[The prepared statement of Chairman Smith follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
March 14, 2018

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement by Chairman Lamar Smith (R-Texas)

National Laboratories: World-Leading Innovation in Science

Chairman Smith: Today, we welcome a diverse group of directors from five of DOE's national laboratories. They oversee innovative work in basic science and early-stage research performed daily by some of the best scientists and researchers in the world.

Our witnesses represent national labs that fulfill the Department of Energy's missions within the Office of Science, applied energy and national security programs. The Science Committee's jurisdiction over the DOE budget includes over $9 billion for civilian research, development, demonstration and commercial application programs, much of which is conducted by the national labs.

Over the past 70 years, this research community has led to monumental achievements in medicine, manufacturing, computing and energy technology development. The labs that are represented here today have made invaluable contributions to U.S. scientific progress and leadership. They have repeatedly demonstrated that basic science research is the most effective way to encourage innovation in technology.

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We look forward to hearing from our witnesses about the potential impact of these upgrades.

It is a central goal of this committee to ensure that our national labs remain the best in the world. To maintain our competitive advantage as a world leader in science, we must continue to support the research that will lead to next generation energy technologies.

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Chairman SMITH. That concludes my opening statement, and the Ranking Member, the gentlewoman from Texas, Ms. Johnson, is recognized for her opening statement.

Ms. JOHNSON. Thank you very much, Mr. Chairman. As a matter of fact, that was an outstanding statement, and I want to thank you for holding this hearing and also from hearing the witnesses from the Department of Energy national laboratories for testifying today. We look forward to it.

Our national laboratories, as we all know, are part of the foundation of the U.S. research enterprise. The work of the scientists and engineers at our labs is truly extraordinary and has been the catalyst for so many scientific and technological breakthroughs. You can look at nearly every growing industry in the United States and see the fingerprints of federally funded R&D and more than likely see the work of researchers at our national laboratories.

Scientific infrastructure and research activities play a vital role in our nation's economic strength, as well as its security, and we need to support them. This year's DOE budget proposal submitted by the Administration is a slight improvement over last year's, thanks in large part to a budget deal we struck here in Congress. While I'm glad to see the Administration is not proposing an overall cut to the Office of Science, I think we can all agree that these vital activities warrant funding increases, not just a continuation of stagnating and declining budgets year in and year out.

A key remaining challenge for DOE's Office of Science is that the dysfunctional congressional budget process has prevented new projects and facility upgrades from moving forward. I hope to work with my colleagues in the House and Senate to ensure that we find a way to fund these important projects as soon as possible.

Beyond the Office of Science, the rest of DOE did not even achieve stagnation in the budget proposal, and the national laboratories are in line to suffer as a result. The Administration is proposing 66 percent cut to the Office of Energy Efficiency and Renewable Energy, a 32 percent cut to the Office of Electricity, and a 25 percent cut to the Fossil Energy R&D, and a 26 percent cut to the Office of Nuclear Energy. These draconian cuts are simply not acceptable.

By all credible accounts, American industry will not fund the activities that are proposed for elimination no matter how much the Administration would like to think so. The Department could have heard that—from industry directly, but the second year in a row we heard from Department officials that they did not formally engage with the private sector in deciding what activities they would cut. However, that did not stop the Administration from rationalizing these cuts by stating that the private sector is better suited to carry out activities that are being cut.

I hope we can get back to reality during this hearing. I'd like to hear from our witnesses who regularly engage with the private sector about how they foresee the private R&D changing if cuts like those proposed are enacted. In almost every case, research funded by the Department is too high risk to attract private sector investment. If the technology matures and the private sector sees an opportunity to profit, I assure you that they will happily find the capital to ensure the technology finds its way to the market.

Our challenge has been that we have trouble moving technologies far enough along the innovation pipeline for this to occur. The problem we are facing is not that our federal R&D budgets are too high or that we're doing too much. Quite the opposite. I have not met a single person with actual industry experience who would advocate for smaller federal R&D budgets.

Now, to be clear, I am not saying that every program the Department currently implements is perfect. We should continue to identify smart reforms and debate our priorities. We must be thoughtful investors of the taxpayers' dollars, but I'm confident that investing robustly in our national laboratories and early and appropriately reviewed later-stage R&D is the right decision.

With that, Mr. Chairman, I yield back.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

Committee on Science, Space, and Technology
"National Laboratories: World-Leading Innovation in Science"
March 14, 2018

Thank you, Mr. Chairman for holding this hearing. I'd also like to thank each of our witnesses from the Department of Energy national laboratories for testifying today. Our national laboratories are part of the foundation of the U.S. research enterprise. The work of the scientists and engineers at our labs is truly extraordinary and has been the catalyst for so many scientific and technological breakthroughs. You can look at nearly every growing industry in the United States and see the fingerprints of federally funded R&D, and more than likely see the work of researchers at our national laboratories.

Scientific infrastructure and research activities play a vital role in our nation's economic strength as well as its security, and we need to support them. This year's DOE budget proposal submitted by the Administration is a slight improvement over last year's, thanks in large part to a budget deal we struck here in Congress. While I am glad to see the Administration is not proposing an overall cut to the Office of Science, I think we can all agree that these vital activities warrant funding increases, not just a continuation of stagnating or declining budgets year-in and year-out. A key remaining challenge for DOE's Office of Science is that the dysfunctional Congressional budget process has prevented new projects and facility upgrades from moving forward. I hope to work with my colleagues in the House and Senate to ensure we find a way to fund these important projects as soon as possible.

Beyond the Office of Science, the rest of DOE did not even achieve stagnation in the budget proposal, and the national laboratories are in line to suffer as a result. This Administration is proposing a 66% cut to the Office of Energy Efficiency and Renewable Energy, a 32% cut to the Office of Electricity, a 25% cut to fossil energy R&D, and a 26% cut to the Office of Nuclear Energy. These draconian cuts are simply not acceptable.

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I hope we can get back to reality during this hearing. I would like to hear from our witnesses, who regularly engage with the private sector, about how they foresee private R&D changing if cuts like those proposed are enacted. In almost every case, research funded by the Department is too high-risk to attract private sector investment. If the technology matures and the private sector sees an opportunity to profit, I assure you they will happily find the capital to ensure the technology finds its way to the market. Our challenge has been that we have trouble moving technologies far enough along the innovation pipeline for this to occur. The problem we are facing is not that our federal R&D budgets are too high or that we are doing too much – quite the opposite. I have not met a single person with actual industry experience who would advocate for smaller federal R&D budgets.

Now to be clear - I am not saying that every program the Department currently implements is perfect. We should continue to identify smart reforms and debate our priorities. We must be thoughtful investors of taxpayer dollars. But I am confident that investing robustly in our national laboratories in early *and* appropriately reviewed later-stage R&D is the right decision.

With that, I yield back.

Chairman SMITH. Thank you, Ms. Johnson.

And I'll introduce our experts today. And our first witness is Dr. Mark Peters, Director of Idaho National Laboratory, and President of Battelle Energy Alliance. Before joining Battelle, Dr. Peters served as the Associate Laboratory Director for Energy and Global Security at Argonne National Laboratory. He currently serves as a Senior Advisor to the Department of Energy on Nuclear Energy Technologies, Research, and Development Programs and Nuclear Waste Policy. As a recognized expert in nuclear fuel cycle technologies and nuclear waste management, he is called upon frequently to provide expert testimony and to advise in formulation of policies for nuclear fuel cycle, nonproliferation, and nuclear waste disposal.

Dr. Peters received a bachelor's degree in geology from Auburn University and his doctorate in geophysical science from the University of Chicago. He has also completed the Strategic Laboratory Leadership Program at the University of Chicago Booth School of Business. He was honored as a fellow of the American Nuclear Society in 2015.

Our next witness is Dr. Susan Seestrom, Associate Laboratory Director for Advanced Science and Technology, and Chief Research Officer at Sandia National Laboratory. Prior to joining Sandia, Dr. Seestrom spent over 30 years at Los Alamos National Laboratory serving in a number of leadership positions including Associate Laboratory Director for Experimental Physical Sciences and Associate Laboratory Director for Weapons Physics. Dr. Seestrom was named a fellow of the American Physical Society in 1994 and served as Chair of the Nuclear Science Advisory Committee for the Department of Energy and the National Science Foundation from 2009 to 2012. In her current role, Dr. Seestrom manages multiple science programs, environmental technologies, computing, modeling, and simulation Laboratory-Directed Research and Development, user facilities, and education programs.

Dr. Seestrom received her bachelor of science and Ph.D. in physics from the University of Minnesota. She is the co-author of over 140 referred publications with over 1,800 career citations. Excuse me.

Our third witness is Dr. Mary Maxon, the Associate Laboratory Director for Biosciences at Lawrence Berkeley National Laboratory. There, she oversees the Biological Systems and Engineering Environmental Genomics and Systems Biology and Molecular Biophysics and Integrated Bioimaging Divisions, as well as the DOE Joint Genome Institute.

Prior to joining Lawrence Berkeley, Dr. Maxon worked in the private sector of the biochronology and pharmaceutical industries and the public sector serving as the Assistant Director for Biological Research at the White House Office of Science and Technology Policy in the Executive Office of the President. With her extensive background in industry, scientific foundations, and state and Federal Government, she is a national leader in science and technology policy.

Dr. Maxon earned her bachelor's degree in biology and chemistry from the State University of New York Albany and her Ph.D. in molecular cell biology from the University of California Berkeley.

Our next witness is Dr. Chi-Chang Kao, Director of the Stanford Linear Accelerator Center, pronounced SLAC, and National Accelerator Laboratory. Previously, Dr. Kao served as Chairperson of the National Synchrotron Light Source at Brookhaven National Laboratory in New York. He joined SLAC as Associate Laboratory Director for the Stanford Synchrotron Radiation Lightsource in 2010 and became the fifth Director in November 2012. He has been named a fellow of both the American Physical Society and the American Association for the Advancement of Science. His research focuses on x-ray physics, superconductivity, magnetic materials, and the properties of materials under high pressure.

Dr. Kao earned a bachelor's degree in chemical engineering from National Taiwan University and a doctorate in chemical engineering from Cornell University.

Our final witness today is Dr. Paul Kearns, Director of Argonne National Laboratory. With nearly three decades of management experience, Dr. Kearns has a strong background in science and engineering, along with extensive experience with the U.S. Department of Energy. Prior to his work at Argonne, Dr. Kearns was Director of the Idaho National Engineering and Environmental Laboratory where he also served as Deputy Laboratory Director and Associate Laboratory Director for Environmental Technology and Engineering. Dr. Kearns has held leadership and advisory roles in the Department of Energy's Office of Energy Management in Washington and in regional offices, including the Chicago operations office.

Dr. Kearns is a fellow of the American Association for the Advancement of Science and a member of the American Nuclear Society. He holds a doctorate and a master's degree in bionucleonics and a bachelor's degree in natural resources and environmental sciences, all from Purdue University.

Among the four experts we have here today, there are at least 50 different titles, an indication of their knowledge and expertise. And so we will begin, and Dr. Peters, if you will lead us off.

TESTIMONY OF DR. MARK PETERS, DIRECTOR, IDAHO NATIONAL LABORATORY

Dr. PETERS. Thank you, Mr. Chairman. Chairman Smith, Ranking Member Johnson, and Members of the Committee, thank you for the opportunity to appear before you today. It's an honor to speak to you about the Department of Energy national laboratories.

I've submitted my written testimony for the record and will summarize it here. My name is Mark Peters, and I'm the Director at Idaho National Laboratory. I'm also serving in a one-year term as Chairman of the National Laboratory Directors Council, an organization created by the Directors of the 17 national laboratories.

A rapidly changing world results in a complex and evolving set of challenges for our nation. Primary among those are insuring our national security at home and abroad; increasing the availability of clean, affordable, and reliable energy; and continuing to enhance U.S. competitiveness in the global market. I am confident in our country's ability to meet these challenges in part because the United States possesses the unique asset: the Department of Energy's national laboratories.

Our laboratories are among the Nation's top science and technology enterprises with a rich history of accomplishment that has driven American prosperity. This Committee's jurisdiction includes the national laboratories, and I believe each of you can take a great deal of pride in the system you've helped build and support.

Our national laboratories are home to state-of-the-art facilities who capably support DOE, the Department of Defense, the Department of Homeland Security, the intelligence community and our military to provide technical solutions to national security challenges.

Finally, our partnership with industry and academia drives technology, science and technology solutions to the marketplace, creating jobs and driving economic growth. But we can never become complacent or be unwilling to honestly assess our strengths and weaknesses and work to improve. I would argue that we can and should strive to do more as a national laboratory system.

In October of 2015 the Commission to Review the Effectiveness of the National Laboratories delivered its first report. We all took careful note of the contents of that report, specifically how the relationship between DOE and its management and operating contractors had, in the words of the Commission, eroded over time. My colleagues and I understand our vital mission to serve the American taxpayers best served by embracing reform and improving the way we operate.

I also want to emphasize that the Department of Energy, under the leadership of Secretary Moniz and now Secretary Perry, is deeply committed to the national laboratories and is partnering with us to improve our effectiveness. Last fall, the National Laboratory Directors Council wrote a letter to Secretary Perry in support of DOE's efforts to drive fundamental change across the laboratories.

As we continue to evolve the relationship between DOE and its M&O contractors, let us focus on the following areas: rebuilding trust between DOE and its contractors; restoring responsibility, authority, and accountability for decisions and performance; bureaucratic reduction; and, when appropriate, the use of consensus standards. We understand that in asking us to be empowered, we also are betting on ourselves, and we need to embrace the culture of safety and transparency.

Now, moving onto the focus of the importance of research and development. Idaho National Laboratory is proud of its status as the nation's leading nuclear energy research and development laboratory. As part of our effort to maintain and extend the lives of the U.S. nuclear fleet, we are working with utilities to modernize control rooms and help transition DOE's Light Water Reactor Sustainability Program to one focused on not only helping with extending licenses but also reducing operating costs.

But it's important to note that if we are to maintain our historic advantage in civil nuclear energy, we must establish private-public partnerships between the Federal Government and the nuclear industry. In that we are working on advanced reactor designs at the laboratory in partnership with industry, and vital to all that is the—vital to all that, we must maintain research and development talent, capabilities, and facilities at the national laboratories. This includes a versatile fast neutron source, which I thank the Committee for strongly supporting. INL is also a multi-program laboratory that addresses a broad range of energy and security challenges, including protecting the grid from cyber attack.

So in the end, our mutual success requires stability. Maintaining our country's leadership in science and innovation requires sustained and strong support and building cutting-edge scientific and engineering facilities and infrastructure and maintaining an outstanding workforce. Other countries are doubling down their investments in government-funded R&D. This threatens our long-held science and technology leadership position. The national laboratory system is strongest when DOE is strong. It is absolutely critical that DOE's core missions have strong support and stable funding across the entire R&D spectrum.

So in closing, DOE is working actively with the national laboratories to make the system more effective and efficient. Secretary Perry and his team are to be commended for spearheading this effort, which cannot help but result in better outcomes for us all. For our part, we at the laboratories are committed to working with Secretary Perry and the DOE to build trust and accountability and ensure the best possible return for the Nation's investment in the DOE national laboratories.

Thank you again for the opportunity to be here and look forward to your questions.

[The prepared statement of Dr. Peters follows:]

TESTIMONY OF

DR. MARK PETERS, LABORATORY DIRECTOR

IDAHO NATIONAL LABORATORY

BEFORE THE

U.S HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NATIONAL LABORATORIES: WORLD-LEADING INNOVATION IN SCIENCE"

March 14, 2018

2318 Rayburn House Office Building

Washington, DC

Dr. Mark Peters, Idaho National Laboratory Director
U.S. House Committee on Science, Space, and Technology
"National Laboratories: World Leading Innovation in Science"

Chairman Smith, Ranking Member Johnson, and members of the committee: Thank you for the opportunity to appear before you today. It is an honor to speak to you about the management, accomplishments, and research goals at our U.S. Department of Energy national laboratories.

My name is Mark Peters, and I am director at Idaho National Laboratory (INL). I am also serving in a one-year term as chairman of the National Laboratory Directors Council (NLDC), an organization created by the directors of the 17 national laboratories.

The value of the national laboratories

A rapidly changing world results in a complex and evolving set of challenges for our nation. Primary among those are:

- Ensuring our national security at home and abroad, and protecting and making more resilient vital infrastructure such as electric grids and transportation systems;
- Increasing the availability of clean, affordable, and reliable energy to meet a growing demand;
- And continuing to enhance U.S. competitiveness in the global market through scientific achievement and innovation.

I am confident in our nation's ability to meet these challenges, in part because the U.S. possesses a unique national asset other nations desperately want to duplicate: our DOE national laboratories.

The national laboratories are among the nation's top science and technology enterprises. This system of 17 laboratories working together to advance science and innovation is uniquely American. 16 of the 17 national laboratories are Federally Funded Research and Development Centers (FFRDCs) and are operated by Management and Operating (M&O) contracts with the Department of Energy.

Our national laboratory system has a rich history of accomplishment that has driven American prosperity. This committee's jurisdiction includes the national laboratories, and I believe that each of you can take a great deal of pride in the system you helped build and support.

The national laboratories exist to promote scientific and technical innovation in the areas of energy, national security, and scientific discovery. By any measure, the national laboratory system has accomplished that mission. I could spend the rest of my time today listing great innovations borne in a DOE national laboratory. I will not do that, but I would point out a few notable achievements:

- **The Internet**
  National laboratory scientists, seeking to share physics information, installed the first web server in North America, jump-starting the development of the World Wide Web.
- **Medical diagnostics and treatment**
  National laboratory researchers helped develop the field of nuclear medicine, producing radioisotopes to diagnose and treat disease, imaging technology to detect cancer, and software to target tumors and spare healthy tissue.
- **Peaceful use of nuclear energy**

I am proud to say that nearly every nuclear energy reactor in use around the globe today can trace its roots to Idaho National Laboratory and its precursors. Our national laboratories are also integral to extending the lives of the U.S. nuclear reactor fleet and developing the next generation of nuclear reactors.

- **Powered NASA spacecraft**
  National laboratories built the nuclear battery that powered the Mars Rover Curiosity and other important NASA space and planetary missions.

Our national laboratories play a critical role in treating and disposing of Cold War nuclear waste and developing advanced technologies, and they are home to state-of-the-art facilities and staff who capably support DOE, the Department of Defense, the Department of Homeland Security, the intelligence community, and our military to provide technical solutions to national security challenges.

Finally, the national laboratories' partnerships with industry and academia drive technology solutions to the marketplace, creating jobs and driving economic growth.

Our national laboratory system is a tremendous asset that gives the U.S. an advantage over the rest of the world. But we can never become complacent, or be unwilling to honestly asses our strengths and weaknesses and work to improve. I would argue that we can – and should – strive to do more.

Improving Efficiency and Effectiveness

In 2014, Congress established the Commission to Review the Effectiveness of the National Laboratories (CRENEL). The commission delivered its first report in October 2015. As a new laboratory director (my first day at INL was Oct. 1, 2015), I took careful note of the contents of that report, specifically the nature of the relationship between DOE and its management and operating contractors, and how that had, according to the commission, eroded over time. "The intended relationship between DOE and the National Energy Laboratories is as trusted partners, working together to carry out critical missions for the Nation," the report said. The erosion of that partnership "resulted in a less-than-optimal working relationship and reduced efficiency."

The 2014 Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise reached the same conclusion, and lamented the loss of a management system that allowed the government to decide what is needed and the M&O contractor to decide how that need is to be met. "The (Federally Funded Research and Development Centers) model for the NNSA labs has been lost," the report concluded. "Historically the Federally Funded Research and Development Centers – the laboratories – have played a key strategic role as trusted advisors in informing the government regarding effective execution of the mission ... the FFRDC role has increasingly been replaced by one whereby the laboratories are perceived as contractors rather than as partners who are relied upon to help resolve issues and successfully deliver the mission."

I can tell you that my colleagues and I take these findings seriously, and we understand that our vital mission to serve the American taxpayer is best served by embracing reform. I also want to emphasize that the DOE, under Secretary Moniz and now Secretary Perry is deeply committed to the national laboratories and are partnering with the laboratories to improve our effectiveness.

Last fall, the National Laboratory Directors Council wrote a letter to Energy Secretary Rick Perry in support of DOE's efforts to drive fundamental change across four key areas:

(1) Focus on national priorities

We do this through strategic planning and working collectively and individually to meet DOE and NNSA mission needs and address national priorities.

(2) Improved DOE governance at the laboratories

DOE has worked to streamline and simplify contract mechanisms that reduce transactional oversight, and allow the M&O contractors a better understanding of expectations and greater authority and accountability in key areas, such as procurement and incident reporting.

(3) Regulatory reform

In accordance with Executive Order 13777, "Enforcing the Regulatory Reform Agenda," the department is prioritizing a reduction of regulatory burdens that impede innovation.

(4) Industry collaboration

We have seen DOE take specific steps to move scientific and technological advances into the marketplace. And the laboratories are being encouraged to work with the private sector to find ways for our R&D to provide pathways that create new businesses, products, and jobs.

As we continue to evolve the relationship between DOE and its M&O contractors, let us focus on the following areas:

- Rebuilding trust between DOE and its contractors.
- Restoring responsibility, authority, and accountability for decisions and performance to the M&O contractors.
- A reduction of bureaucracy, specifically duplicative, contradictive, and unnecessary requirements.
- And, when appropriate, the use of consensus national, international, commercial, industrial, and institutional standards.

The Revolutionary Working Group contract negotiated at SLAC National Laboratory was an effort to redesign the M&O contract in a way that enabled an increased level of efficiency and effectiveness. In a limited sample size, this approach has resulted in reductions in transactional oversight, increases in private investment, and a reduction in operating costs.

I believe empowering the M&O contractors managing the laboratories will result in the most effective use of our taxpayer dollars. As we allow the laboratories to hire good people, provide them with the tools they need, demand results, and hold them accountable, we will unleash the genius of our national laboratories.

DOE, Congress, and the national laboratories should partner to continue to develop and test new contracting mechanisms that allow for greater collaboration with industry and less cumbersome oversight. Hold the laboratories accountable, but let us work together to develop innovative contracting, partnership, and oversight models to see what we might achieve.

We understand also that in asking to be more empowered, the laboratories are betting on ourselves. We need to embrace a safety culture and transparency, and we must conduct business in a way that will make our fellow citizens proud. We need to admit mistakes when they occur, correct them, and learn from them. Let our national laboratories lead the way in establishing cultures of transparency, accountability, and accomplishment.

The Importance of Research and Development (R&D)

The core mission of the 10 DOE Office of Science Laboratories is to pursue basic research for the advancement of scientific knowledge for fundamental discovery and to provide the foundation to addressing energy and security challenges. This does not necessarily have specific near-term commercialization objectives or applications.

The core mission of the applied energy laboratories is two-fold:

- Research, development, and demonstration (RD&D) for the ultimate application of new knowledge having specific performance objectives with respect to products or processes;
- And to act as the technical resource for the country in the areas of specific expertise. In this role, the applied energy laboratories provide the nation with expert advice and serve as honest brokers between industry, government, and regulators on all aspects of the appropriate energy technology or security system.

Moreover, the applied energy laboratories serve the public interest for access to safe, secure, sustainable, reliable, and resilient energy by developing, validating, and demonstrating at scale, new technologies in their areas of specialty. The applied energy laboratories have a strong public purpose, but also work at the nexus of government and industry, often addressing problems that are neither purely governmental nor purely private, but where there is a clear national interest. Examples include the development of advanced energy technologies, solutions to maintain grid reliability and resilience, and management of used nuclear fuel.

Finally, there are legitimate and essential federal government roles in reducing risk to induce private investment that go beyond basic science in the arena of technology development, validation, and commercialization of energy systems. The laboratories serve an essential role in this part of the science and innovation ecosystem.

INL is extremely proud of its status as the nation's lead nuclear energy R&D laboratory, and its history of helping build an industry that provides nearly 20 percent of this nation's electricity and 60 percent of its carbon-free electricity. An industry that is responsible for 500,000 direct and indirect jobs and adds $60 billion annually to the U.S. gross domestic product. As part of the effort to maintain and extend the lives of the U.S. nuclear reactor fleet, INL is working with utilities to modernize control rooms based on decades-old technologies. That includes digital instrumentation and controls.

The Laboratory is supporting utilities in the license renewal process. This effort has helped three utilities determine they will seek "Subsequent Licensing Renewal," which extends the life of a power plant beyond 60 years. Finally, we have transitioned DOE's Light Water Reactor Sustainability (LWRS) Program, from one concerned primarily with licensing to include helping utilities reduce operating costs. We realized that plants who get relicensed will struggle to continue operating if they are not economically sustainable.

If we are to maintain our historic advantages in the civil nuclear sector we must enable the private-public partnerships necessary to develop and deploy the next generation of nuclear reactors. Building a first-of-its-kind reactor is expensive and risky. Our national laboratories are ideal places to do the research and development and partner with industry to demonstrate new technologies. A current example is the emergence of light-water small modular reactors (SMRs).

INL also is working on advanced reactor designs, including high-temperature gas reactors cooled by molten salt or helium gas, liquid metal reactors cooled by sodium, and reactors that feature liquid fuel dissolved in fissile and fertile materials with molten salt coolant. These advanced technologies will not only further the role of nuclear energy in the production of clean, reliable, resilient, and affordable electricity, but also take advantage of other attributes, like nuclear process heat, to transform the transportation and manufacturing sectors. This will require continued research and development investments and robust private-public partnerships.

In the next few years, for example, we are excited to work with the private sector to develop and demonstrate microreactor technologies. Think of the possibilities: powering remote communities and military bases around the world, as well as the ability to react quickly to natural disasters such as the hurricane that devastated Puerto Rico's electricity generation system, and rebuild systems that are more reliable and resilient to future threats.

Key to these advanced reactor technologies, INL and our partner laboratories are working to develop advanced nuclear fuels and new cladding materials to operate at higher temperatures, extract more energy from the fuel, tolerate a wider range of operating and abnormal conditions, and reduce waste generation. Developing new materials and fuels for nuclear energy systems requires world-leading test reactors and post-irradiation examination and fuel science capabilities, like the Advanced Test Reactor (ATR) at INL, High Flux Isotope Reactor (HFIR) at ORNL, and Materials and Fuels Complex (MFC) and Transient Reactor Test Facility (TREAT) at INL.

To further U.S. leadership in the science and technology of advanced nuclear energy systems, we are also exploring the development and design of a Versatile Fast Neutron Source (VFNS) within a decade. The irradiation capabilities of the VFNS will foster further innovations by our national laboratories, universities, and industry for many decades to come.

INL, as a multi-program national laboratory, also addresses broader energy and security challenges. For example, our scientists are working in advanced manufacturing, hybrid energy systems, and electric vehicles. And INL's National and Homeland Security Directorate is committed to protecting the reliability and resiliency of our power grid and energy infrastructure. Our Cybercore Integration Center initiative facilitates research and development that identifies vulnerabilities and develops solutions to reduce cyber risks.

In summary, the national laboratories meet the special, long-term needs of the nation that cannot be met in any other way. Continued investments in these vital national assets will boost our economy, protect our national security, protect our environment, and benefit our citizens in a variety of ways difficult to imagine. Additional DOE national laboratory accomplishments that further illustrate these points include:

- **Purified vaccines**

National laboratory researchers adapted nuclear separations technology to develop a zonal centrifuge used to purify vaccines, which reduces or eliminates unwanted side effects. Commercial centrifuges based on the invention produce vaccines for millions of people.

- **The "Fracking" revolution**
  National laboratory research jump-started the shale gas revolution by pointing the way to key technologies and methodologies for cost-efficient extraction. An estimated $220 million in R&D expenditures on unconventional gas R&D from 1976 to 1992 have resulted in an estimated $100 billion in annual economic activity from shale gas production alone.
- **Delivered troops safely**
  National laboratory researchers have developed computer models that effectively manage the complex logistical tasks of deploying troops and equipment to distant destinations.
- **Made wind power mainstream**
  Increasing wind turbine efficiency with high efficiency airfoils has reduced the cost of wind power by more than 80 percent over the last 30 years. Now deployed in wind farms nationwide, these turbines owe their existence to national laboratory research.
- **Improved airport security**
  Weapons, explosives, plastic devices, and other concealed tools of terrorists are easier to detect thanks to technology developed at national laboratories and now installed in airports worldwide.
- **Clean up Anthrax**
  National laboratory scientists developed a nontoxic foam that neutralizes chemical and biological agents. This foam was used to clean up congressional office buildings and mail rooms exposed to anthrax in 2001.
- **Launched the LED lighting revolution**
  In the 1990s, national laboratory scientists saw the need for energy-efficient solid-state lighting and worked with industry to develop white LEDs. Today, white LEDs are about 30 percent efficient, with the potential to reach 70 percent to 80 percent efficiency.

Private-public Partnerships

While federal government funding is vital to ensuring the success of our national laboratories, the importance of private-public partnerships cannot be overstated. The close relationship of applied energy laboratories, in particular, with the private sector ensures transition of knowledge and technologies into commercial products and practices that are market relevant.

That certainly applies to private-public partnerships that may end up being a game changer for the American nuclear energy industry. INL has partnered with NuScale Power and their Small Modular Reactor (SMR) from the beginning, providing technical support and guidance. And NuScale's first SMR is planned for the INL desert Site. A private-public partnership has been vital to the project's success, and will continue after the SMR begins producing electricity for the Utah Associated Municipal Power Systems (UAMPS) in 2026. Eventually, up to two of NuScale's 12 50-megawatt modules might also be dedicated to research and development. The Joint Use Modular Plant (JUMP) program would allow INL to use one or two of the modules to demonstrate other energy processes, such as thermal energy storage and hydrogen production. Working with our industry partners, we will examine how we can use energy differently in the future, and create more integrated systems, including safe, secure, and resilient micro-grid systems.

This private-public partnership is just the beginning and this R&D is vital. But so is achieving results. Accelerating innovation and getting ideas into the marketplace is a necessary part of realizing nuclear energy's enormous potential and maintaining the United States' historic leadership. That is why DOE established the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative. This collaborative effort between INL, Oak Ridge National Laboratory, and Argonne National Laboratory provides the nuclear community with access to the technical, regulatory, and financial support necessary to move innovative nuclear energy technologies toward commercialization. GAIN provides an opportunity for the private and public sectors to share expertise, reduce barriers, and successfully develop innovative nuclear technologies.

A plea for stability

Maintaining our country's leadership in science and innovation requires sustained and strong support in building cutting-edge scientific and engineering facilities and infrastructure, and maintaining an outstanding workforce. Other countries are doubling down their investments in government-funded R&D. In fact, other countries are basing their planning on DOE and its national laboratory system. This threatens the U.S.'s long-held science and technology leadership with implications for the economy, national security, and environmental sustainability. The national laboratory system is strongest when DOE is strong. That is why it is critical that DOE's core missions have strong support and stable funding across the entire R&D spectrum.

And we all would benefit from a return to a stable federal funding process. Operating under continuing resolutions and the threat of government shutdowns is demoralizing. It is also an inefficient and ineffective way to manage agencies, departments, laboratories, and science and technology. When the television news is dominated by the approach of another government shutdown date, our workforce – talented people dedicated to the mission of leaving this world a better place than they found it – cannot be blamed if they spend time wondering about their next paycheck instead of their next scientific breakthrough.

Closing

I began by talking about the challenges our nation faces today, and into the future, and how I believe our national laboratories are ideally suited to foster the scientific achievement and innovation necessary to overcoming those challenges. I want to end by saying that DOE is working actively with the national laboratories to make the system more effective and efficient. Secretary Rick Perry, Deputy Secretary Dan Brouillette, and the DOE team are to be commended for spearheading this effort, which cannot help but result in better outcomes vital to our national security, environment, and economy. For our part, the laboratories are committed to working with Secretary Perry and the DOE to build trust and accountability and ensure the best possible return for the nation's investment in the DOE national laboratories.

Thank you again for the opportunity to be here today. I am happy to answer any questions you may have.

Idaho National Laboratory

Dr. Mark Peters, Laboratory Director

Dr. Mark Peters is the director of Idaho National Laboratory and president of Battelle Energy Alliance, LLC. His credentials and experience include leadership and management of large institutions with substantial efforts focused on technology research and development. Prior to joining Battelle, he served as the associate laboratory director for Energy and Global Security at Argonne National Laboratory. Dr. Peters serves as a senior adviser to the Department of Energy on nuclear energy technologies, research and development programs and nuclear waste policy.

As a recognized expert in nuclear fuel cycle technologies and nuclear waste management, he is called upon frequently to provide expert testimony to Congress and to advise in formulation of policies for nuclear fuel cycles, nonproliferation and nuclear waste disposal. In 2015, he was honored as a Fellow of the American Nuclear Society for outstanding accomplishments in the area of nuclear science and technology. He serves on the ANS Public Policy Committee, and served on the executive committee of the ANS Fuel Cycle and Waste Management Division. Earlier in his career, he worked in science and research positions at both Los Alamos National Laboratory and the California Institute of Technology. Dr. Peters received his doctorate in geophysical sciences from the University of Chicago and a bachelor's degree in geology from Auburn University. He has received extensive management and leadership education and training, including completion of the Strategic Laboratory Leadership Program at the University of Chicago Booth School of Business.

Chairman SMITH. Thank you, Dr. Peters.
And, Dr. Seestrom.

TESTIMONY OF DR. SUSAN SEESTROM, ADVANCED SCIENCE AND TECHNOLOGY ASSOCIATE LABORATORY DIRECTOR AND CHIEF RESEARCH OFFICER, SANDIA NATIONAL LABORATORY

Dr. SEESTROM. Chairman Smith, Ranking Member Johnson, and distinguished Members of the Committee, I thank you for the opportunity to testify today about the role of engineering, science, and technology at Sandia National Laboratories, the Nation's largest federally funded research and development center. I'm Susan Seestrom, Associate Laboratories Director for Advanced Science and Technology and Chief Research Officer.

There's four points I would like to emphasize in my testimony today. The first is that Sandia National Laboratory's core mission is to ensure the safety, the security, and the effectiveness of our nation's nuclear deterrent.

My second point is that our ability to carry out that mission rests on our strong foundation as a science-based engineering laboratory.

My third point is that the scientific capabilities that we've developed in executing our mission for the nuclear deterrence are often applied to other missions of DOE and other government agencies.

And finally, as an FFRDC national security lab, Sandia requires the flexibility to pursue forward-leaning research and development so that we can anticipate and prepare for national security challenges beyond the present scope of programs.

As an engineering lab, our purpose at Sandia is to develop advanced technology to ensure global peace, and that mission is—mainly sees itself in our nuclear deterrence. As one of three NNSA laboratories, Sandia provides foundational science and engineering to the NNSA in order that they can maintain and modernize the nuclear stockpile and ensure its effectiveness in an evolving international landscape.

We at Sandia have the responsibility for the weaponization of the nuclear explosives through weapons system engineering and the integration of nonnuclear components into the nuclear explosive packages that are designed by our sister NNSA laboratories. Nuclear deterrence has been our core mission for almost 70 years, and the complex and multidisciplinary nature of that mission has enabled us to solve some of the most pressing national security challenges facing the country in areas such as nonproliferation, energy, and cybersecurity.

We conduct such work for a number of government stakeholders beyond the NNSA, including the broader DOE, the Department of Homeland Security, and DOD. This work enables us to strengthen our key expertise, our expertise in key areas, invent new and unique solutions to problems, and to nurture our R&D staff. Our Laboratory-Directed Research and Development program, or LDRD, is essential to us as our primary source of discretionary research fund. In a future of rapidly evolving threats, LDRD provides us with flexible resources and the agility we need to anticipate and prepare for national security challenges that are beyond the horizon of present programs. Sandia needs its LDRD to invest in long-term, high-risk, and potentially very high payoff R&D that stretches the lab's science and engineering capabilities. We also use partnering with industry, academia, and other labs to extend our foundational research understanding and contribute results that are important to us and to our partners.

I would like to close my testimony with one example of the synergy that I've tried to describe above. There are more examples in my written testimony. A series of projects over ten years sponsored by various sources, including Laboratory-Directed Research and Development, deepened our understanding of semiconductor physics. Standard semiconductors are susceptible to natural and hostile environment radiation sources that our nuclear weapons can be expected to encounter. We developed a scientific understanding of the rich material science and special processing techniques that allowed us to design radiation resistance directly into our semiconductor devices at our Microsystems Engineering and Science Applications capability, MESA. MESA is the only U.S. facility to produce strategically radiation-hardened microelectronics for the nuclear weapons complex.

Sandia's rad hard semiconductor devices reduce the development costs of the W76–1 Life Extension Program, and Sandia is now scheduled to produce more than 40,000 rad hard integrated circuits for the stockpile modernizations over the next 10 years.

With that, I thank you for your attention and the opportunity to testify here today.

[The prepared statement of Dr. Seestrom follows:]

Statement of Dr. Susan Seestrom
Associate Laboratories Director, Advanced Science & Technology
Chief Research Officer
Sandia National Laboratories

Committee on Science, Space, and Technology
United States House of Representatives
March 14, 2018

Introduction

Chairman Smith, Ranking Member Johnson, and distinguished members of the Committee on Science, Space, and Technology, I thank you for the opportunity to testify today on the role of science, engineering, and research at Sandia National Laboratories, one of the nation's premiere national labs and the nation's largest Federally Funded Research and Development Center (FFRDC) laboratory. I am Dr. Susan Seestrom, Sandia's Associate Laboratories Director for Advanced Science & Technology (AST) and Chief Research Officer (CRO). As CRO I am responsible for research strategy, Laboratory Directed Research & Development (LDRD), partnerships strategy, and technology transfer. As director and line manager for AST I manage capabilities and mission delivery across a variety of the physical and mathematical sciences and engineering disciplines, such as pulsed power, radiation effects, major environmental testing, high performance computing, and modeling and simulation.

Prior to joining Sandia, I spent 30 years at Los Alamos National Laboratory, first as a scientist performing basic and applied research in nuclear physics and later in a variety of leadership positions, including Associate Laboratory Director for Experimental Physical Sciences and previously Associate Laboratory Director for Weapons Physics.

Sandia is a multimission laboratory owned by the U.S. Government and operated and managed by National Technology and Engineering Solutions of Sandia (NTESS), LLC[1] for the National Nuclear Security Administration (NNSA), part of the U.S. Department of Energy (DOE). Sandia currently operates with an annual budget of just over $3 billion and has grown to more than 12,200 workforce members plus contractors to meet all mission commitments. NNSA owns all Sandia facilities and is the sponsor of Sandia's FFRDC status. Industrial, academic, and nonprofit organizations have

[1] National Technology and Engineering Solutions of Sandia, LLC. is a wholly owned subsidiary of Honeywell International Inc. under Department of Energy prime contract no. DE-NA0003525. SAND2018-2460 R.

historically managed the DOE national laboratories and other major government-owned contractor-operated facilities.

As an FFRDC, Sandia meets special long-term research and development needs for the country. FFRDC status also means that Sandia operates in the public interest with objectivity and independence, is free from organizational conflicts of interest, and fully discloses its affairs to the sponsoring agency. Sandia operates as an autonomous organization or as an identifiable separate operating unit of a parent organization. Sandia does not use privileged information to compete with the private sector but may perform work for agencies other than its parent agency when the private sector is not able to perform specific work those agencies require.

Major Points of this Testimony

1) Sandia National Laboratories' core mission is to ensure the safety, security, and effectiveness of the nuclear deterrent.
2) Sandia's role in the nuclear deterrent mission rests on our strengths as a science-based engineering lab with capabilities that enable us to contribute world-class science to the nation. Our science and engineering capabilities are essential to solving current problems and anticipating and developing solutions to future national security challenges.
    a) Sandia does not stand alone—we build on and support the work of other DOE labs, industry, and academia to create a deep nationwide pool of expertise and capabilities.
3) Because the deep scientific capabilities from our role in the NNSA nuclear deterrent mission, Sandia has expertise that we can extend to other DOE missions, including those advanced by DOE's Office of Science and Office of Energy Efficiency and Renewable Energy.
4) Sandia must also independently pursue research and development we have identified as critical to our many missions. Our Laboratory Directed Research & Development Program gives us the agility to pursue ideas that have the potential to broadly impact national security challenges today and in the future.

History of Sandia National Laboratories

Sandia's roots can be traced to the Manhattan Project and Los Alamos. In July 1945, J. Robert Oppenheimer established Z Division at Sandia Base in Albuquerque to perform stockpile development and non-nuclear component engineering. In 1949, at the urging of the Atomic Energy Commission, President Truman encouraged American Telephone and Telegraph Company (AT&T) to manage and operate Sandia as it separated from Los Alamos. In his letter to AT&T President Leroy Wilson, Truman captured what has become the spirit of Sandia: "In my opinion, you have here an opportunity to render an *exceptional service in the national interest*." AT&T Bell Laboratories operated Sandia from November 1949 through 1992. In 1993, Martin Marietta Corp. became the management and operating contractor for Sandia National Laboratories, later merging with Lockheed to form Lockheed Martin Corp. Lockheed Martin operated Sandia Labs and managed Sandia Corporation until April 30, 2017.

On May 20, 2015, DOE announced its intention to compete the contract for Management and Operation (M&O) of Sandia. Following a full and open competition that generated unprecedented interest from across industry[2], on Dec. 16, 2016, NNSA announced it had awarded the M&O contract for Sandia to NTESS. A transition period began in January 2017 and NTESS officially transitioned to the M&O contractor for Sandia on May 1, 2017.

Given the rarity of such changes, DOE/NNSA, Sandia Corporation leadership, and incoming NTESS leadership were committed to minimizing the impacts of the contract competition on Sandia and helping employees focus on safely, securely, and efficiently delivering on Sandia's national security missions. The transition did result in turnover and reorganization of the executive leadership ranks. However, there were no reductions in workforce, and Sandia is expected to grow by a few hundred employees in fiscal year 2018.

In the months following May 2017, Sandia has had several notable accomplishments. Sandia delivered the Annual Stockpile Assessment letter on schedule, continued execution of stockpile life extensions programs (LEPs) and alterations (ALTs) on schedule and on budget, had major successes with a hypersonic test flight and on Z experiments, and earned five R&D 100 awards. Informal assessments of employee morale after the transition appear positive; an all-employee survey was conducted in December 2017 and the results of that survey are expected in the coming weeks.

Nuclear Deterrence: Our Core Mission

Sandia's purpose is to develop advanced technologies to ensure global peace, primarily manifested through our core mission in nuclear deterrence. As one of three NNSA laboratories, Sandia has a critical role helping NNSA sustain and modernize the stockpile, providing foundational science and engineering capabilities to advance and sustain an effective nuclear deterrent in an evolving landscape. Sandia has responsibility for the weaponization of nuclear explosives through warhead system engineering and integration of non-nuclear components with the nuclear explosive packages designed by our two sister NNSA laboratories, as well as integration of the warhead with the delivery system, design of non-nuclear components including arming, fuzing, and firing systems, neutron generators to initiate nuclear yield,

[2] https://nnsa.energy.gov/mediaroom/pressreleases/nnsa-awards-sandia-national-laboratories-management-operating-contract

gas transfer systems, and critical nuclear safety and security systems. In addition, Sandia produces neutron generators and trusted specialty components. Within the U.S. nuclear weapons enterprise, Sandia is uniquely responsible for the systems engineering and integration of the nuclear weapons in the stockpile and for the design, development, qualification, sustainment, and retirement of nonnuclear components of nuclear weapons.

Sandia accomplishes these tasks using our capabilities in numerical simulation, physical sciences, and large-scale systems testing. Together, these capabilities give us an exquisite ability to predict the performance of nuclear weapons systems and components without underground weapons testing. Our resources in modeling and simulation combine to produce intellectual leadership in our workforce; a suite of tools for ensuring that weapon systems will survive current and anticipated conditions throughout their lifetimes; and the ability to sustain, modernize, design, produce, secure, and employ a portfolio of weapon systems that are flexible and responsive to changing requirements and threat conditions. Much of that modeling and simulation and experimental work is conducted on behalf of NNSA's Research, Development, Test, and Experimentation (RDT&E) program.

An example of this work is Sandia's operation of large-scale test facilities for ensuring the safety and reliability of nuclear weapons systems by simulating natural and induced environments to evaluate performance during transportation, launch, re-entry, and impact. Data from these tests validate computer models used to more fully understand and predict system performance. Sandia test facilities include lighting simulation; a rocket sled track to study impacts and aerodynamics; equipment to test acceleration, deceleration, and vibration; and unique facilities for testing the effects of extreme heat, radiation, and pressure.

While Nuclear deterrence has been Sandia's core mission for nearly 70 years, the complex and multidisciplinary nature of this mission means Sandia is a source of essential science, technology, and engineering to resolve the nation's most challenging security issues. We leverage the skills, knowledge, and facilities required to design, deploy, and maintain the nation's nuclear deterrent to support other aspects of national security, including nonproliferation, energy security, and cybersecurity. We conduct that work for a host of stakeholders in addition to NNSA, including DOE, the Department of Homeland Security, the Department of Defense, and others. Examples of areas where Sandia has applied the synergy between our core nuclear weapons mission and our broader national security work include high-resolution radars that see through clouds and darkness; an adaptive, lightweight, and extremely accurate zoom riflescope prototype to aid our warfighters; satellite sensors that help the nation monitor worldwide nuclear activity from space; and technology that dramatically improves the endurance of legged robots to aid in disaster response. Technologies Sandia has developed and successfully transferred to industry include cleanrooms for microelectronics manufacturing, triggers for automobile airbags, and a device known as the Air Bearing Heat Exchanger, or "Sandia Cooler," with the potential to dramatically alter the electronics chip-cooling landscape in computing.

Sandia: A Multi-Program, Science-Driven Engineering Lab

The synergy between our nuclear deterrent mission and our broader missions is made possible by the relationship between science and engineering at Sandia. Science asks why; engineering asks how. Science enables new tools and technology, and the engineering behind these tools and technology likewise enable new science in a "virtuous cycle" or positive feedback loop. In other words, science enables engineering advances that in turn allow scientists to ask new questions and find groundbreaking results. Researchers can think beyond the confines of a specific challenge to ask how Sandia and the United States can prepare for constantly changing threats to national security and the constantly evolving technology that contributes to those threats. When scientific research begins to conceptualize and understand those threats in theoretical space, engineers can begin the hard task of building solutions that address threats in the real world. The engineering advances intended for specific challenges can also contribute to unexpected scientific breakthroughs and a research and development environment characterized by creativity, innovation, and engaged staff.

For example, beginning in the 1960s as part of Sandia's mission to test weapon components in hostile radiation environments, Sandia has become the world leader in trillion-watt pulsed power science and technology, with the expertise needed to safely and efficiently operate pulsed power facilities. The 80-trillion-watt Z machine, the present world-leading pulsed power facility, efficiently creates extreme states of matter to address a broad range of nuclear weapon science issues. Beyond that mission, pulsed power offers the promise of a path to high-yield fusion for future weapons science studies and even fusion ignition. The high pressures and temperatures attained are also relevant to fundamental science such as astrophysics and planetary science.

At Sandia, the fundamental scientific research that underlies our nuclear deterrent mission also underpins our ability to work for stakeholders beyond NNSA, especially the DOE Office of Science and other DOE programs. These sustained programs help us to pursue foundational research and build essential skills, expertise, and capabilities. In particular, our Office of Science programs serve a crucial role in allowing us to bring unique value to the DOE Office of Science, executing long-term scientific research on complex challenges beyond the capabilities of academia and industry. These efforts also enable us to deepen our strength in key areas by allowing us to develop and maintain unique scientific capabilities and nurture R&D staff.

For example, Sandia's research and development on hydrogen isotope gas transfer systems, first undertaken in the nuclear weapons programs, enabled our deep understanding of hydrogen effects on solid materials and broader contributions to the

DOE Fusion Energy Science and Fuel Cell Technologies for Transportation missions. Our research on the fundamental materials science of hydrogen was made possible largely by Office of Science funds, and that work furthered our capabilities for safe and reliable design of hydrogen systems. That understanding in turn informed our research on hydrogen embrittlement in aging weapons systems.

Similarly, investment at Sandia in compound semiconductor materials research, heavily funded by the Office of Science Basic Energy Science/Materials Science & Engineering program yielded not only key contributions to the solid-state lighting revolution but to rad-hard heterojunction bipolar transistors critical to the life-extension programs for strategic re-entry systems.

Another prime example of our Office of Science efforts is the Center for Integrated Nanotechnologies (CINT) managed by Sandia in partnership with Los Alamos National Laboratory. CINT, one of five DOE Basic Energy Sciences-funded NanoScale Research Centers, makes use of a wide range of specialized facilities including the Microsystems Engineering, Science, and Applications (MESA) facility, the Ion Beam Facility (IBL) at Sandia, and the National High Magnetic Field Laboratory at Los Alamos. CINT's vision is to become a world-leading resource for developing the scientific principles that govern the design, performance, and integration of nanostructured materials into the micro and macroscale worlds. This differentiating focus on nanomaterials integration involves the experimental and theoretical exploration of behavior over multiple spatial and temporal length scales, the development of novel synthesis and processing approaches, and an understanding of emergent behavior and new performance regimes.

CINT focus areas are quantum materials; in-situ characterization and nanomechanics; soft, biological, and composite nanosystems; and nanophotonics and optics. CINT has been especially successful in creating a growing number of Discovery Platforms that provide windows into the nanoscale dynamic properties of materials, a more meaningful measure of how nanosystems act in the real world. CINT has an impact far beyond Sandia and our missions: As a user facility, it provides researchers from universities, other national laboratories, and industry open access to our specialized instrumentation and expertise for experiments not possible at their home institutions. Over 12 years, CINT has served almost 5000 users from 44 states and yielded 2,430 refereed publications.

Sandia is also a key participant in DOE's Exascale Computing Project (ECP), helping to advance application development and software technology for computing systems that are 50 to 100 times faster than the most powerful supercomputer in use today. The Exascale Computing Project is funded by both the DOE Office of Science and NNSA, consistent with the DOE mission to harness exascale computing power to improve U.S. economic competitiveness, national security, and scientific discovery. The ECP is therefore like many Sandia research efforts in that it brings together fundamental and applied science that spans nuclear weapons and many other national security missions.

Sandia's specific role in exascale computing is to provide leadership on software technology and advanced architectures to contribute to development of a software stack for exascale applications and architectures. Sandia also supports the development of operating systems, scalable solvers, performance portability, visualization software, and other key technologies. In addition to high-performance computing research for our nuclear deterrence mission, Sandia is involved with five Office of Science exascale application projects: We are leading work on applications simulating combustion engines and on clouds in the Earth's climate, and contributing to projects on wind energy plants, molecular dynamics, and quantum mechanics-based materials simulations.

Energy: An Important Sandia Research Focus

It is significant that much of our work on exascale computing and other Office of Science-related activity involves energy. Our defense preparedness and economic competitiveness are driven by the reliability and resilience, cost effectiveness, and technology advancement for our nation's energy systems—energy security and national security are closely intertwined. Sandia builds on the foundation created by its national security R&D to help create a secure energy future for the United States. Our technologies help plan for an uninterrupted and enduring supply of energy from domestic sources and assure the reliability and resiliency of the energy infrastructure. We seek a sustainable energy future by developing energy sources that are safer, cleaner, more economical and efficient, and less dependent on scarce natural resources.

For example, the CINT Office of Science program at Sandia has conducted fundamental scientific research that could be used for improvements in hydraulic fracking technology, aiding U.S. energy independence and our nation's economy. The R&D staff, skills, and capabilities behind that research are available at Sandia to pursue similar work in the future.

We conduct critical research and development on transportation energy security at the Combustion Research Facility (CRF), an internationally recognized DOE Office of Science-sponsored collaborative effort. CRF scientists, engineers, and technologists conduct basic and applied research aimed at improving our nation's ability to use and control combustion processes. Knowledge gained from this research is transferred to industry to improve fuel efficiency and reduce emissions in light-duty and heavy-duty engines while enabling the diversification of fossil and bio-derived fuel sources. Research ranges from studying chemical reactions in a flame to developing laser diagnostics to observe mixing and combustion inside engines. We leverage our expertise in modeling and high-performance computing to develop predictive engineering models based on our physical observations and measurements. Work at the CRF therefore gives Sandia staff experience that extends to our core ND mission and other research. For example, Sandia researcher Jacqueline Chen was recently elected to the National Academy of Engineering for her contributions to the computational simulation of turbulent reacting flows with complex chemistry, which has ramifications far beyond the CRF.

Sandia R&D Builds and Depends on Partnerships

The CRF is a powerful example of the importance of partnerships to Sandia and our research. Much of the work at the CRF is done in collaboration with scientists and engineers from industry and universities. Every year, more than 100 visiting researchers collaborate side by side with CRF staff to develop new research methods and approaches, conduct experiments exploiting new facilities and techniques, and solve high-priority combustion problems. Our ability to attract the best researchers from around the world amplifies the DOE investment.

Overall, Sandia's industrial partners are numerous; CRF partners alone include every U.S. automaker, General Electric, John Deere, and Cummins, as well as ExxonMobil, Chevron, and Shell. In the past five years, Sandia has signed almost 4,000 partnership agreements (primarily including no fee agreements, cooperative research and development agreements, and license/government use notices) with more than 2,000 business partners, including small and startup businesses. Sandia's extensive partnering relationships with industry, academia, and other labs on complex research problems extend our foundational research understanding and contribute results that are applicable for both our partners and national security. Partnerships also create a community of U.S. scientists and engineers ready to promote innovation in many fields. Partnerships also benefit American consumers: Products that have become a part of peoples' daily lives and support the nation, such as solid-state lighting and high efficiency engines, came from Sandia R&D that was commercialized. Finally, partnerships feed back to our core mission: Sandia recently marked 25 years of working with The Goodyear Tire and Rubber Company through a CRADA to create better tires. In the process, Sandia has gained additional capabilities and expertise in computational mechanics that can be applied to other missions.

LDRD: Advancing our Research Capabilities

The LDRD program is an essential component in Sandia's research and development effort. LDRD is our primary source of discretionary funds, resources we can allocate to strategic research and development that is flexible and agile enough to anticipate and prepare for challenges beyond the horizon of present programs to a future of rapidly evolving threats. The LDRD program allows Sandia to invest in long-term, high-risk, and potentially high-payoff R&D that builds, maintains, and stretches the Labs' science and engineering capabilities, including our R&D staff. These capabilities form the bedrock of our nuclear deterrence mission. LDRD funds are also essential to Sandia's ability to anticipate and respond to evolving threats, one of our roles as an FFRDC.

The importance of LDRD funding to Sandia's core nuclear weapons mission is demonstrated by a series of projects from 1996 to 2007 that developed radiation-hardened trusted application-specific integrated circuits (ASICs). Standard semiconductors are vulnerable to radiation from natural sources and hostile environments, but these integrated circuits are critical to nuclear weapons, as well as nonproliferation and other national security applications. Using LDRD funds, Sandia developed a scientific understanding of the rich materials science and special processing techniques that allow us to design radiation-protection directly into chips. Sandia's radiation-hardened ASICs were an element of reducing the development costs of the W76-1 life extension program, and Sandia is now scheduled to provide more than 40,000 radiation-hardened ASICs to the nation's B61-12, W88 ALT 370, and Mk21/W87 stockpile modernization over the next 10 years.

In another example, in 2011 Sandia researchers initiated a microsystems-enabled photovoltaics (MEPV) LDRD project with the goal of developing a next-generation photovoltaic system with 40 percent conversion efficiency and the ability to provide power cost-competitive with the grid. The project resulted in tiny glitter-sized photovoltaic cells fabricated of crystalline silicon using microelectronic and microelectromechanical systems techniques common to today's electronic foundries. Sandia's MEPV technology led to 49 patent filings, seven issued patents so far, and a 2012 R&D100 award.

MEPV technology has since taken a significant step toward commercialization. In 2017, the Albuquerque startup mPower Technology Inc. licensed the technology for its Dragon SCALEs, small, lightweight, reliable, efficient, and flexible solar cells that fit into and power devices or sensors of any shape or size. The high-efficiency cells can be integrated into drones, biomedical and consumer electronics, and even wearable formats, and can be folded like paper for easy transport. Beyond the technology's obvious benefits in providing off-the-grid power for a host of applications and in reducing U.S. dependence non-renewable imported power, Dragon SCALEs will bring much-needed high-tech jobs to New Mexico. Like many civilian technologies developed with LDRD funds, MEPV also has potential for national security applications in satellites or in powering gear used by forward-deployed ground forces.

Projects funded through Sandia's LDRD program have impacts far beyond their original intent. The Ultra-Wide-Bandgap LDRD project developed the next generation of semiconductors that will enable ultra-compact and robust power converters for nuclear weapons systems, an important contribution to ensuring a safe, secure, and effective stockpile. In addition, the technology will also lead to ultra-efficient power converters for a more resilient electric power grid, winning Sandia a 2017 R&D 100 award.

The common threads linking these LDRD projects are Sandia's facilities for, experience with, and deep staff understanding of microsystems research, development, and prototyping. Sandia's work on semiconductors began in the late 1950s, when the shift from vacuum tubes to semiconductor electronics in weapons systems raised concerns about those electronics' vulnerability to radiation. Separately, in the late 1970s DOE Office of Science funding allowed Sandia to expand its research on compound semiconductors, which offered advantages such as greater radiation and temperature resistance than silicon semiconductors. Compound semiconductors, including heterojunction bipolar transistors, have since become essential to nuclear weapons and other national security applications. Today, Sandia's capabilities in this field are centered at the MESA complex, which integrates the scientific disciplines and fabrication facilities needed to research, design, and produce functional, robust, and integrated microsystems for national security and other applications. MESA is the only facility able to produce trusted strategically radiation-hardened microelectronics for nuclear weapons and other national security applications.

Our history in semiconductors demonstrates how Sandia research that began from two independent starting points —nuclear weapons survivability and fundamental scientific research on semiconductors — has come together to further Sandia's many missions. That virtuous cycle continues today. The recently launched Strategic Inertial Guidance with MAtterwaves (SIGMA) LDRD project seeks to dramatically reduce the size, weight, and power requirements for an inertial sensor based on atom-interferometer (AI) technology, an effort made possible by Sandia's microelectronics R&D facilities and expertise. SIGMA is focused on improving the navigational capabilities of weapons systems, but the project could also lead to quantum sensors, a technology with potential in medicine, telecommunications, and other applications. Finally, the SIGMA project shows the importance of a research and development community that extends far beyond Sandia and the national labs. The atom-interferometer technology and other advances that make the project possible have their origins in academic and commercial research, and Sandia's ability to solve future security challenges cannot succeed without these partners.

In addition to funding specific projects, the LDRD program at Sandia helps us build science and engineering capabilities by attracting and retaining a world-class research community. LDRD allows Sandia to fund innovative research by early-career R&D staff, and relatively new employees perform a large percentage of LDRD research at the labs. For FY2014-2016, about 35 percent of LDRD labor charges were made by Sandia R&D technical staff with less than five years of service, including postdoctoral research staff. Among the full-time regular R&D staff with graduate degrees who power Sandia research, those funded by LDRD are more likely to stay at Sandia: For every three R&D graduate-degree staff who leave Sandia each year, only two LDRD-funded staff leave. Today's early career staff will in the future be leaders at Sandia, continuing our tradition of delivering exceptional service in the national interest to solve the unprecedented and unknown challenges to come.

Susan J. Seestrom

Susan Seestrom has been Associate Laboratories Director for Advanced Science and Technology and Chief Research Officer at Sandia National Laboratories since May 2017.

Prior to coming to Sandia, Susan spent 30+ years at Los Alamos National Laboratory. Susan first came to Los Alamos as graduate student pursuing her Ph. D. in experimental nuclear physics at the University of Minnesota. She subsequently joined Los Alamos as a Directors Fellow and continued as a member of the scientific staff. Dr. Seestrom's research in nuclear physics ranges from studies of nuclear structure with medium energy probes to studies of the weak interaction using neutrons. Dr. Seestrom initiated efforts to develop a source of ultra-cold neutrons (UCN) at Los Alamos. This work culminated in a world-leading UCN source at Los Alamos and the first measurement of the beta asymmetry in neutron decay using UCN. She most recently was a Senior Fellow at Los Alamos, working as part of a collaboration measuring the neutron lifetime using UCN.

Susan served in a number of leadership position at Los Alamos over 13 years. She most recently served as Associate Laboratory Director for Experimental Physical Sciences at Los Alamos National Laboratory from 2006 to 2013, and was Associate Laboratory Director for Weapons Physics from 2004 through 2006. Prior to that she has was the Division Leader of the Physics Division and Deputy Group Leader for Neutron Science and Technology at Los Alamos.

Dr. Seestrom is the co-author of over 140 referred publications. She was named Fellow of the American Physical Society in 1994. She has been an active member of the American Physical Society, serving in various capacities, including: Executive Committee of the Division of Nuclear Physics (1993-1994); Nominating Committee of the DNP (1995-1996, Chair 1996); Program Committee of the DNP (1986-1987,1997-1998,2004 Vice Chair, 2005 Chair); Fellowship Committee of the DNP (1997-1998); General Councilor of the APS (1996-2000); Executive Board of the APS (1998-2000); Chair Committee on Meetings APS (1999) Nominating Committee of the APS (2002-2004, Chair in 2003); Chair, Chair-Elect, and Vice Chair of the Division of Nuclear Physics (2004-2007). She served as Chair of the Nuclear Science Advisory Committee for the Department of Energy and the National Science Foundation (2009-2012).

Chairman SMITH. Thank you, Dr. Seestrom.
And, Dr. Maxon?

TESTIMONY OF DR. MARY E. MAXON, ASSOCIATE LABORATORY DIRECTOR FOR BIOSCIENCES, LAWRENCE BERKELEY NATIONAL LABORATORY

Dr. MAXON. Chairman Smith, Ranking Member Johnson, and distinguish Members of the Committee, thank you for holding this hearing and for the Committee's support for science.

My name's Mary Maxon, and I'm the Associate Laboratory Director for Biosciences at Lawrence Berkeley National Lab, a DOE Office of Science lab managed by the University of California. It's my honor to participate in this hearing. Thank you for inviting me.

Berkeley Lab was founded in 1931 by Ernest Orlando Lawrence, UC Berkeley physicist who won the 1939 Nobel Prize for physics for inventing the cyclotron. Lawrence and his colleagues discovered that scientific research is best done by teams of people with different fields of expertise working together. This teamwork concept is a Berkeley Lab legacy reflected throughout the national lab complex today. With five national scientific user facilities that are used by around 11,000 users annually Berkeley Lab is a key part of the Nation's scientific and innovation infrastructure.

Today, we're a multipurpose lab, delivering world-leading advances in energy, materials and chemical sciences, biosciences, earth sciences, and physics. Other countries are busy building their own national labs. The time is now to invest strategically to ensure that our advantages don't disintegrate and leave us behind.

Fortunately, progress is being made from upgrading our light sources to the exascale computing initiative. Positive actions are being taken by this Committee and the Department to ensure that American researchers have access to the very best, and this is good news. Other areas, more attention is required.

Renewing laboratory infrastructure—utilities, water drainage, buildings—is needed to support modern research. Although the Office of Science is addressing this aggressively, much more is needed. We encourage the Committee to address this long-term challenge.

Another long-term challenge is ensuring a diverse and talented workforce at the labs. Cultivating talent and promoting inclusion is central to the creation of a successful work environment, driven by a diversity of thought, partners working toward shared objectives. Among the national labs, Berkeley Lab was the first to publish workforce diversity statistics. We know that our success as a national lab depends upon our ability to create a community that brings together people with diverse backgrounds, points of view, and approaches to problem-solving. This is critical.

In my remaining time, I'd like to describe how the labs succeed by integrating unique resources and world-leading expertise. National labs play a key role in our innovation ecosystem, uniquely talented equipped to tackle grand challenges by integrating resources and expertise at a scale and breadth impossible by other institutions.

The labs also provide a longer-term outlook on success than is available within industry, one that can take science from the bench to the user facility and ultimately to collaboration with industry and the marketplace. One really exciting example is the microbiome for energy and environmental sustainability. It's got great promise, but it's a tough scientific nut to crack. Microbes are the most abundant life form on earth. In a handful of soil, there are more microbes than stars in our galaxy. They exist in a network of communication and collectively work to impact their environments, whether healthy soils for agriculture or the biodegradation of toxic pollutants.

Deciphering this world of microbiomes is a huge undertaking. It's like taking 1,000 puzzles, each with thousands of pieces, and then scattering them in a pile and trying to reconstruct them without a picture. It requires a national lab.

Genome sequencing, engineering biology, advanced high-performance supercomputing, success here could mean more productive energy crops, faster remediation of contaminated soils, and new bioproducts to fuel the Nation's bio-economy. In this and other examples, there are no bright lines between fundamental research, applied R&D, and commercialization. It's a continuum. The national laboratories work well along this continuum and play a key role in shepherding discoveries to the point of commercial viability.

A recent example is the Agile BioFoundry. Established in 2016 by EERE, the BioFoundry is a biological engineering platform that aims to reduce the time and cost of producing biofuels and bioproducts, a difficult challenge. The BioFoundry is a consortium of eight national labs established in response to industry, the need that was articulated at listening days with industry representatives. They specifically identified issues that are beyond their capacity to address.

It's now a scientific platform de-risking a number of technologies, and a recent solicitation shows that there's a significant demand for this type of research. Nineteen companies applied for $20 million in requested funds, four times more than what is available.

I thank you for the opportunity to testify at this important hearing. I'm happy to answer your questions.

[The prepared statement of Dr. Maxon follows:]

NATIONAL LABORATORIES: WORLD-LEADING INNOVATION IN SCIENCE

A Hearing of the

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

Testimony of

DR. MARY MAXON, ASSOCIATE LABORATORY DIRECTOR FOR BIOSCIENCES
LAWRENCE BERKELEY NATIONAL LABORATORY

March 14, 2018
2318 Rayburn House Office Building
Washington, DC

INTRODUCTION

Chairman Smith, Ranking Member Johnson, and distinguished Members of the Committee, thank you for holding this hearing and for the Committee's support for science. My colleagues at Berkeley Lab and I are particularly grateful for the legislation moved by the Committee authorizing critical parts of the Office of Science and its network of national user facilities. These bills are very important to the future of the national laboratory system. At Berkeley Lab we are particularly grateful for Congressman Steve Knight and his authorship of H.R. 4376 which authorizes the upgrade of the Advanced Light Source, one of our signature national user facilities. Thank you.

My name is Mary Maxon and I am the Associate Laboratory Director for Biosciences at Lawrence Berkeley National Laboratory, a DOE Office of Science laboratory managed by the University of California. It is my honor and my pleasure to participate in this hearing and to aid the Committee's examination of the great contributions made by the Department of Energy's national laboratories to the nation's scientific and technological innovation. Thank you for inviting me to testify.

I would also like to express my thanks and the thanks of Director Witherell and the entire staff of Lawrence Berkeley National Laboratory to Secretary Perry, Undersecretary Dabbar, Office of Science Deputy Director Steve Binkley, the Associate Directors of the Office of Science and the scores of program managers for their consistent support for what we do. Additionally, I'd like to recognize and express our appreciation for the partnership we have with the DOE Berkeley Site Office and its Director Paul Golan.

The positive engagement with the national laboratories at the highest levels of the Department has been extremely helpful and very productive. The Committee should know this, and Departmental leadership should be appropriately recognized for their strong support for the mission and well-being of the labs.

In a specific example at Berkeley Lab, we are grateful for the partnership with the Berkeley Site Office and with headquarters in the rewriting of the management contract with the University of California under the auspices of the Revolutionary Working Group contract reform successfully undertaken first at SLAC. The initiative is attempting to build upon the work and recommendations of the CRENEL report and other studies, as well as on legislation promulgated by this Committee, such as H.R. 589 that addresses the labs' ability to be a better partner for industry. The process is moving forward and we are confident that the end result will help Berkeley Lab fulfill its mission for the Department and the nation more efficiently.

My testimony will attempt to do four things.

First, describe Berkeley Lab and its unique role in the nation's system of national laboratories.

Second, describe how the national laboratories are the ultimate integrators of science and technology development for the national good. They have a unique role in the national research enterprise, one that relies on close partnerships both with industry and with academic laboratories.

Third, discuss why moving science and technology from the lab bench, or national user facility, to commercial viability and society is not simply a bucket brigade from research to development to deployment. Moving an innovation quickly to commercial deployment requires regular interaction between early-stage researchers, late-stage developers, and the companies that know how to introduce products into the marketplace.

And, **fourth,** explain why the national labs must not be taken for granted but nourished and supported. Countries in Europe and Asia have realized that the national laboratory system has provided a competitive advantage to the United States, and they are working quickly to reproduce it.

The investments must be made today and continually to: support cutting edge, world leading scientific user facilities; ensure the labs have secure, safe and modern infrastructure; and enhance the workforce pipeline to guarantee the recruitment and retention of diverse and world leading scientific and operations staff.

BERKELEY LAB

Berkeley Lab was founded in 1931 by Ernest Orlando Lawrence, a UC Berkeley physicist who won the 1939 Nobel Prize in physics for his invention of the cyclotron. A circular particle accelerator, the cyclotron is the original ancestor of today's great accelerators and light sources and opened the door to high-energy physics and expedited new discoveries in diverse fields from materials and chemical sciences to biosciences and health care. Lawrence and his colleagues discovered that scientific research is best done through teams of individuals with different fields of expertise, working together. This teamwork concept is a Berkeley Lab legacy that shaped the

Manhattan Project and continues today and is reflected throughout the national laboratory complex. Berkeley Lab has moved from being a fundamental physics laboratory to one with world leading expertise and capabilities across core Office of Science mission needs and DOE applied energy research and development objectives.

With five national scientific user facilities that are utilized by around 11,000 researchers annually, Berkeley Lab is a key part of the nation's scientific and innovation infrastructure. From the world's most advanced electron microscope at the Molecular Foundry that can pinpoint how individual atoms are arranged in a material, to the world's most scientifically productive supercomputer at the National Energy Research Scientific Computing Center with its 7,000 users, researchers are attracted to Berkeley Lab, as they are to other DOE national laboratories, because of the unique capabilities and expertise they find at Berkeley Lab.

NATIONAL LABS AS INTEGRATORS

The Members and staff of this committee recognize well that American innovation is underpinned by a complex ecosystem consisting of people, ideas and tools that is envied by and unmatched in the world. This system grew out of a post-World War II commitment made by the federal government to support scientific research conducted at U.S. universities and national laboratories.

In today's highly competitive global environment, the U.S. innovation ecosystem is one of our nation's most precious assets. The federal government has a fundamental responsibility to keep this ecosystem healthy, because it gives the nation a powerful competitive edge, providing solutions to major national challenges and fueling economic growth. At the same time, universities and laboratories have a fundamental responsibility to be sensible stewards of taxpayer funds, conduct first-rate research on key scientific and technological problems with intellectual rigor and efficient use of resources, and strive to transfer the results of this research to industry and to markets for the benefit of society as a whole.

As many of you already know and as others will learn today, the national labs play a central role in the nation's innovation ecosystem. They are uniquely and, in some cases, singularly equipped to tackle grand challenges and opportunities because they integrate world class scientific user facilities, science and engineering experts, whole communities of scientific disciplines and researchers, and industrial needs and knowhow at a scale and breadth impossible by other institutions – in the U.S. or around the world.

Government leaders from around the world visit our national labs to understand how they are managed and organized. Some of these nations are investing heavily in an attempt to reproduce the laboratory system that we often take for granted.

Thousands of academic and industrial scientists from every state in the union, close to 1,000 from the State of Texas alone, leverage the national laboratories' facilities and scientific expertise to advance their own research. In total, over 33,000 researchers use DOE Office of Science national scientific user facilities to conduct cutting edge research. Democratic and merit based, these facilities are available to researchers with the best scientific ideas, as determined by external review committees who rank the value of the proposed research based on the quality of the science, the appropriateness to the facility, and the potential contribution to scientific knowledge. These facilities include world class supercomputers, large x-ray light sources, neutron sources and other unique instruments.

And, instead of the federal government replicating these large scale, unique facilities for each of the science agencies that require their capabilities, at a cost of billions of dollars, access to DOE scientific user facilities is agnostic to the source of funding and open to all comers - this is a tremendous asset for other federal agencies such as NSF, NASA, USDA, NIH, DOD, and NIST and for industry. Around 15,000 U.S. users of DOE's facilities have no DOE funding for their research project, a number that grows significantly if you add in researchers who are funded by DOE, other agencies, industry, foundations, and private institutions. This leveraging of DOE facilities across the entire spectrum of the nation's innovation ecosystem provides a great return on the federal investment in U.S. science infrastructure.

Additionally, the national laboratories bring together large teams of researchers to capture opportunities and address challenges at scale - much in the same way that Ernest Lawrence did in the first half of the 20th Century. It made sense then and makes a lot of sense today. National laboratories have the flexibility and the breadth to respond to national mission needs, utilizing the suite of national user facilities across the DOE complex, marshalling the research expertise of their scientists, and partnering with universities and industry. With national goals and objectives in mind, national laboratories, through the support of the Office of Science and other DOE programs, provide a longer term outlook on success. An outlook and an approach that can focus basic science capabilities on use-inspired objectives and address the challenges and opportunities from more of a turnkey perspective - taking the science from the bench, to the user facility, to collaboration with industry and finally to the marketplace.

The journey of science and technology to the marketplace and to the benefit of society does not follow a straight line. Nor is it a case of simply tossing technology over a transom to industry, hoping that its value will be recognized and that industry and investors will flock to it. As you know, it is a much more complicated and nuanced challenge. In other words, there are no bright lines between fundamental science, applied research and development, and commercialization.

The national laboratories, in large part serendipitously, have become ideal environments in which to shepherd discoveries to the point of commercial viability - the point at which industry and investors determine that the technology is de-risked enough to attract adequate venture capital or other forms of financing. Berkeley Lab and labs throughout the complex are experimenting with new ways to engage industry and speed the delivery of novel solutions to the marketplace. In addition to traditional technology transfer activities, such as licensing deals, royalty agreements, and spin-offs, Berkeley Lab has created new activities and have grown other, less traditional, forms of industry engagement.

One good example is Cyclotron Road. A first of its kind program, which has now been replicated at other national laboratories, Cyclotron Road aims to bridge the "valley of death" and bring "hard" tech innovations to commercial viability by spinning into the Lab (not spinning off) small startups with big ideas. Cyclotron Road innovators are embedded in the heart of one of the world's most formidable research and innovation ecosystems. With unencumbered access to collaborations with scientists and faculty at Berkeley Lab and UC Berkeley, its innovators are able to work hand-in-hand with world-leading facilities and experts across nearly all fields of science and engineering.

Since its founding in 2015 more than $45 million in additional early-stage funding has been generated by Cyclotron Road innovators on the basis of solid science and well prototyped technology. And because the small start-up companies that "spin in" to the national lab are largely comprised of early career researchers, the Cyclotron Road effort may well be on its way to training the next generation of industry leaders through a novel partnership paradigm where national lab assets and experienced mentors can greatly accelerate the success of small companies. From materials and manufacturing, to electric power and storage, transportation, and electronics and computing, Cyclotron Road's innovators are developing technologies across a broad range of fields and industries with the potential to transform the world.

Berkeley Lab, as other national laboratories do, continues to attract and work with industry through the national user facilities and large research programs such as the Joint Bioenergy Institute and the Joint Center for Artificial Photosynthesis. Increasingly, industry reps are serving key roles on lab and research advisory boards and review committees.

OPPORTUNITIES

By now, most of you and much of Washington understand that some of our nation's scientific infrastructure is old - a lot of it, in fact - including at our national laboratories. Even so, our entrepreneurial spirit, our ecosystem of innovation as described above, and our culture of creativity and discovery continue to provide us with inherent advantages.

Times are changing however. Learning from our success, other countries are building more technologically advanced light sources, bigger laser research facilities, more powerful supercomputers, etc. The time is now for the United States to invest and ensure that our advantages don't disintegrate and leave us behind in the delivery of key scientific resources and capabilities to American researchers at the labs, in academia, and within industry.

World Leading Scientific Facilities

That is why this Committee's action on user facilities and the Department's initiative to upgrade its national user facilities are so very important. Young, passionate scientists, especially the best of the best, will have to go where they can conduct the most cutting edge and transformational research. As a nation, we must ensure that the place to do that is here, at our national laboratories, at our universities, and within our industries. The President's budget contains good news on this front, especially for the Office of Science Basic Energy Sciences program and its light sources. Berkeley Lab is particularly pleased with the FY19 budget's proposed funding for upgrading the Advanced Light Source. After its upgrade, the ALS will be the premier light source in the world for the delivery of soft x-ray light and should retain this title for years - attracting the best of the best from the U.S. and from around the world.

We are also excited about the Department's exascale computing initiative and Berkeley Lab's role in bringing it to productive fruition. Congressional leaders on this Committee, like Congressman Hultgren, Congresswoman Lofgren and others, have made the nation's high performance computing capabilities a key focus of their policy goals and early on led the fight to advance U.S. supercomputing. As we embark on the path to exascale computing, Berkeley Lab's NERSC, the workhorse computing facility for scientific output for the Office of Science research programs, looks forward to delivering exascale capabilities to the broader scientific community.

Additionally, the Congress and the Department have demonstrated their support for upgrading ESnet - DOE's advanced scientific network. ESnet currently moves ~730 petabytes of data per year. With exascale capable computers coming online the size of yearly data is expected to increase to ~7 exabytes in 2021. For context, remember that 1 exabyte is a unit of information equal to one quintillion (10 to the 18th) bytes, or one billion gigabytes. ESnet's upgrade is critical to the success of the Department's exascale program.

Plant and Facilities Infrastructure Renewal

An issue that you may not know about is the state of our national laboratories' basic plant infrastructure - the electrical and water systems, the condition of the building stock, roads, etc. Because the labs are old - several buildings at Berkeley Lab that are still in use today were built in the 1940s - and because the pace of maintenance, repairs and replacements have not kept up with the need, there is now a large and expensive backlog of deferred actions. At Berkeley Lab, the estimated cost of deferred maintenance is significant. Although much of it is non-critical, some of it is. This scenario is repeated across the entire laboratory complex.

Fortunately, over the past several years, DOE's Office of Science Science Laboratories Infrastructure office has engaged in a proactive and prioritized strategy to first deal with the most urgent issues and to work its way down the list across the entire laboratory complex. All the Office of Science laboratories have benefited from this strategy. At Berkeley Lab, we have been able to tackle critical infrastructure needs and have replaced subpar and unsafe structures with new facilities. Currently, Science Laboratories Infrastructure is constructing the Integrative Genomics Building at Berkeley Lab. This state of the art building will house the Joint Genome Institute, currently located 20 miles away in Walnut Creek, California, and KBase. Both programs are described later.

Even though progress is being made, it's a hard job, deciding how much funding to divert from science for more mundane, if critical, basic infrastructure projects. Ultimately, however, this is a false choice - a commitment must be made to do both. Failing basic infrastructure makes the science superfluous. I urge the Committee to explore the infrastructure issue and to work closely with the Department and the White House and with the appropriations committee of jurisdiction to find solutions to this long term challenge.

Ensuring a Diverse and Talented Workforce

Another critical part, the most important part, of the nation's scientific infrastructure are the men and women who conduct the science as well as those who provide the much needed administrative, financial, technical, and health and safety support. Although the narrative of the brilliant solo scientist persists in today's culture, in fact most scientific research is conducted by teams of people rather than single investigators. Scientific discovery is fueled by creativity and perseverance, and progress is often made when diverse perspectives allow problems to be seen from a variety of different angles.

Successful scientific work environments are those where promising new ideas are fostered and researchers are encouraged to push beyond conventional schools of thought. At national labs, researchers from a broad range of scientific disciplines who have been trained at universities around the world come together to solve national-scale challenges, and many of those challenges sit at the intersections of scientific fields where expertise in single disciplines is insufficient to address them. Supporting these challenging research efforts are dedicated operations staff, without whom scientific progress would be impossible.

Cultivating talent and promoting inclusion is central to the creation of a successful work environment driven by a diversity of thought partners working toward shared objectives. Among the national labs, Berkeley Lab was the first to publish its workforce diversity demographics. From the undergraduate population through senior lab leadership, Berkeley Lab tracks and posts its numbers of women, under-represented minorities, other people of color, two or more races/ethnicities, and whites.

Berkeley Lab believes that with greater diversity in our leadership and throughout the lab, more family-friendly policies, and training in implicit bias for search committees, we have made a strong start. But it is only the beginning of a process that requires continual improvement. We are committed to long-term efforts to ensure that diversity, equity, and inclusion become hallmarks of the Berkeley Lab culture. Though this will require steady attention and effort, we know that our success as a national lab depends upon our ability to create a community that brings together people with diverse backgrounds, points of view, and approaches to problem-solving, and who are committed to bringing science solutions to the world.

CONCLUSION

Thank you, again, for the opportunity to testify at this important hearing. In summary, I applaud the work of the Committee to address the following issues and encourage you to continue to work together, with the Administration, and with other key committees to continually make progress on:

- Ensuring U.S. international leadership in the delivery of state of the art national scientific user facilities with cutting edge research capabilities;
- Explore ways to address the much needed renewal of the national laboratories' aging plant and facilities infrastructure;
- Examining and creatively approaching new ideas to increase the diversity of our national laboratory workforce in ways that attract the best of the best.

Finally, below are examples of science at Berkeley Lab and among our partners and collaborators that illustrate how national labs succeed through integration of resources and capabilities.

I am happy to answer any questions and Berkeley Lab is always pleased to assist the Committee in its work on issues of national importance.

EXAMPLES OF SCIENTIFIC AND TECHNOLOGY INTEGRATION AND INDUSTRY ENGAGEMENT

1. BIOSCIENCES

While Berkeley Lab may be best known for its physical, chemical, and material sciences, the biological sciences have been part of its DNA almost from the beginning when Lawrence recruited top-flight scientists to UC Berkeley in the 1930s.

Lawrence's younger brother John, a physicist and physician, is considered the father of nuclear medicine. At Berkeley Lab, John studied the biological effects of the byproducts of the atom smashers Ernest built, and carried out the first successful treatment of human disease with radioisotopes. Today nuclear medicine still plays a central role in the diagnosis and treatment of cancer and other human diseases, and today's health-related scientists at Berkeley Lab are building on these foundations in their research efforts to better understand cancer, DNA repair, genome structure and function, and neurodegenerative diseases.

Biochemist Melvin Calvin used radioactive carbon-14 from a Berkeley Lab cyclotron to map the route that carbon travels through a plant during photosynthesis — research that led to discovery of the "Calvin cycle" and the Nobel Prize in Chemistry in 1961. Today's physical bioscientists and engineers at Berkeley Lab are building on advances in the physical sciences and modern biology, including those of Calvin, to examine, characterize, and mimic biological molecules and molecular functions to create unique biological structures that can then be used to solve some of the 21st century's most difficult fundamental research problems.

Berkeley Lab conducted path-breaking research on medical imaging, including early development of computed tomography (CT) scans and positron-emission tomography, (PET) scans. Cancer studies broadened to include tracking the behavior of healthy and malignant cells in culture and animals, pioneering the development of 3-D human tissue models, defining cancers as diseases of tissue microenvironments, and identifying many of the impacts of radiation on cells and organisms. Studies of heart disease and Alzheimer's disease helped to characterize the role of oxygen radicals in aging and disease. Bioscience research at Berkeley Lab deepened our understanding of what was becoming known as "systems biology."

The extensive work in biological sciences and pioneering studies on mapping and sequencing the genome of the model organism *Drosophila melanogaster* led to selection of Berkeley Lab as one of five centers for the Human Genome Project, the massive national effort to map and sequence the entire complement of human DNA. Berkeley Lab's Human Genome Center, which was consolidated into the Department of Energy Joint Genome Institute (the DOE JGI) in Walnut Creek, was responsible for sequencing a significant portion of the human genome. Since that time, the DOE JGI has undertaken a considerable effort to determine the genome sequences of thousands of plants and microorganisms with the aim of using this genomic information to develop solutions to national-scale energy and environment challenges.

Aided by faster computers and more advanced algorithms, studies of gene regulation intensified. Berkeley Lab played a major role in the Model Organism Encyclopedia of DNA Elements Project, which resulted in greatly improved genome annotations and scientific understanding of non-protein coding RNAs, chromatin "landscapes," and genome functions. Rapid sequencing renewed interest in proteins, including how they are structured and how they work. X-ray crystallography at the Advanced Light Source, plus a range of powerful microscopic techniques, revealed structures of important proteins at the highest resolutions ever.

The focus on genetics and molecular biology developed naturally toward the discipline now called synthetic biology, which holds the promise of reducing dramatically the costs and time required to design, build, and characterize biological systems. These innovations have led to focused applications and the creation of a number of spin off companies.

The United States has the potential to produce over 1 billion tons of non-food, non-feed biomass that can be mobilized to expand the bioeconomy. In 2012, the National Bioeconomy Blueprint highlighted the opportunities in energy and manufacturing resulting from this strategic resource. Recent assessments have concluded that these opportunities could expand the bioeconomy, adding $259 billion and 1.1 million jobs to the US economy by 2030. Berkeley Lab embarked on an intensive effort to use the tools of genetics, supercomputers, and microbiology to develop biofuels and new sources of sustainable energy. The Joint BioEnergy Institute is one of three national centers created by the DOE in 2007, and expanded to four in 2018, to advance the development of biofuels and biomass derived products.

Building on a legacy of advanced research in biosciences, Berkeley Lab has the infrastructure and expertise to bring biological solutions to the energy, health, and environmental challenges of our time as well as provide the foundational underpinnings for a strong biological manufacturing industry.

In addition to our focus on using science to bring solutions to the world, our strategy also embraces a Berkeley Lab commitment to transferring our knowledge to our surrounding communities. We will continue to combine our research efforts with efforts to reach out to our neighbors. Through workshops, internships, and educational programs at local schools, colleges, and universities, we will promote understanding of science and encourage young people of diverse backgrounds to make a career in biosciences part of their own strategic plans.

Today, I'd like to share some examples of how Berkeley Lab's Biosciences programs address national-scale scientific challenges.

Genomic Sciences

Genome sequencing has evolved from a highly-specialized technology requiring rooms of equipment to one that will soon be democratized through the use of small, portable sequencers barely larger than a thumb drive. At the same time as the speed and availability of sequencing is increasing dramatically, ever more complicated organisms and now communities of microbes are being sequenced. Indeed, the diversity and scale of data generation is growing significantly across the spectrum of biological research, including genome data, advanced imaging analyses, diverse measurements of biomolecular structure and function, spatial and temporal structuring of biological system population genetics, biologically influenced environmental processes, metabolic modeling, and an expanding array of fermentation processes for fuels and chemicals. Biological data generation is increasing at a rate that outpaces Moore's law, meaning that we cannot rely on hardware alone to tackle these data challenges. Scientists and engineers, drawn from across the national lab complex, will be needed to develop new algorithms, standards, and tools that ensure access of biological scientists to state-of-the-art high performance computing. This will be particularly important in the exascale environment in which hardware and software are likely to be co-designed for specific applications.

Recognizing that data collection and standardization will be crucial for unlocking new insight into microbial community functions and importance, Berkeley Lab is leading efforts, with university partners, to establish the National Microbiome Data Collaborative. The collaborative will be a hub for microbiome data and related analysis tools. In addition to this effort, Berkeley Lab is home to the DOE Joint Genome Institute and the DOE Systems Biology Knowledgebase. As I mentioned earlier, the Joint Genome Institute provides advanced genome sciences technologies for scientists studying organisms important to DOE's energy and environment missions. The Systems Biology Knowledgebase is a platform for data and tools designed to accelerate research about microorganisms, plants, and their communities in an environmental context with an emphasis on DOE goals. It makes these data and tools accessible to scientists in a user friendly format, allowing them to gain tremendous insight into the workings of organisms without need expertise in data and computing sciences. The Joint Genome Institute and the Systems Biology Knowledgebase are integrating their data and platforms, allowing users around the world unparalleled access to their expertise in genome sciences, data analysis, metabolic modeling, and computational methods for application to challenging questions in energy and environment.

Advanced Biofuels and Bioproducts

Central to the mission of the DOE national labs is developing the fundamental science and technologies that will ensure that the U.S. can meet its energy needs. Biology can play a significant role in this space to create the bio-based fuels, chemicals, and products that utilize our strategic biomass resources. Converting the billion tons of potentially available non-food, non-feed biomass into useful materials requires fundamental and use-inspired research and development to develop efficient biological conversion processes. These approaches draw inspiration from nature by manipulating the natural processes within organisms and from the ways that humans have used microorganisms and fermentation to create food and beverages. The Joint BioEnergy Institute (JBEI), established in 2007 and recently renewed in 2017, takes an integrated approach to developing new bio-based fuels and chemicals. JBEI is based on the concept of integration - bringing together under one roof the expertise, knowhow and unique resources of five national laboratories and six universities from around the nation, and with the collaboration and integration of industry researchers, all working side by side with shared objectives.

Researchers at JBEI are probing the biological mechanisms behind biomass structure and resilience in order to develop better bioenergy crops that can be more readily deconstructed to useful molecular building blocks and that can withstand environmental stressors. Other members of the JBEI team are developing new bioenergy crop deconstruction approaches that are efficient and minimize contamination. JBEI scientists are also engineering microorganisms to convert the biomass building blocks from deconstruction processes to gasoline, jet and diesel fuels, and useful bioproducts that can reduce the overall cost of production. All of these efforts are underpinned by technology development that strives to increase the throughput and efficiency of production while minimizing costs, time, and energy intensity. Since its inception, JBEI has demonstrated an impressive track record of success in driving solutions to the marketplace. The numbers tell a great story: 713 publications; 26,600,000 citations; 89 IP licenses; 174 patent applications; 35 patents issued; and 6 startup companies.

Another multidisciplinary team science approach to solving national-scale biological challenges and driving the national bioeconomy is the Agile BioFoundry. The Agile BioFoundry was established, in response to industry need, as a consortium of eight national labs (Argonne, Berkeley, Idaho, Los Alamos, NREL, Oak Ridge, Pacific Northwest, Sandia) in 2016 by DOE's Office of Energy Efficiency and Renewable Energy. It aims to unite the unique and differentiated capabilities of the national labs to develop an integrated biological engineering platform that can reduce the time and cost of producing biofuels and bioproducts. The core of the Agile BioFoundry platform is an integrated Design-Build-Test-Learn cycle meant to speed the development of new production organisms by applying machine learning and statistical methods to designing biological routes to products while incorporating techno-economic analyses, life cycle assessments, and measurement at industry scales. Many of the technologies that are being implemented in the Agile BioFoundry were initially developed at the Bioenergy Research Centers, and many more are being jointly developed by the eight national lab team; the Agile BioFoundry is integrating those technologies and de-risking them for eventual implementation by industry.

The Agile BioFoundry was established in response to a number of industry listening days where industrial biotechnology company representatives articulated research needs that were beyond their capacity to address. The first listening day in 2013 was held in Washington, D.C. to bring together thought leaders from industry with Federal funding agencies. These discussions highlighted the "valleys of death" between the published work performed at universities and at the national labs funded by the U.S. government and the what is considered "ready" for commercialization by industry. In the industrial biotechnology industry, these valleys include computer-assisted design tools for designing organisms that can produce products of interest to industry, optimized organisms that can reliably produce these products at scale, and cutting-edge analytical technologies to assess production efficiently. Two additional listening days were held, one in Berkeley, CA and one in Washington, D.C., to engage industry members in the planning of the Agile BioFoundry. These listening days served two purposes- first, to identify the core pre-competitive technologies that the Agile BioFoundry could de-risk for industry; second, to ensure that the Agile BioFoundry brings the full value of the national lab capabilities to bear on challenging biological engineering problems that industry cannot solve alone.

Many technologies developed through fundamental or use-inspired research are proof-of-principle and not yet suited for deployment in the private sector, and a need exists to more fully develop or "harden" the technologies for use in production settings. The Agile BioFoundry runs campaigns to continually improve predictive design tools and to generate publicly accessible data about organism performance and pathways for full public benefit. And in an effort to identify and address more specific challenges that would benefit industry advancement broadly, the Agile BioFoundry has embarked on seven two-year projects with small companies resulting from a recent solicitation where companies were invited to submit proposals for Agile BioFoundry consideration. Some of the chosen projects focus on the informatics tools and data analysis activities of interest to industry while others support the development of key microbial organisms that may eventually be commercialized. The Agile BioFoundry's recent solicitation shows that there is significant demand for this type of national lab research; 19 companies applied for a total of $20M in requested funds, four times the amount of funding available through the solicitation. The Agile BioFoundry established an industry engagement team comprised of industry advisors who help to continually assess the pre-competitive challenges that the Agile BioFoundry could address for and with the industrial biotechnology industry.

Microbiome Research and Development

Berkeley Lab researchers and scientists across the national lab complex are at the forefront of microbiome research for energy, environment, and agriculture. Most people don't know it, but there are more microbes in a handful of dirt than there are stars in our galaxy. And, these microbes don't exit as solitary entities, but as actors in a well choreographed interchange of activity - activity that determines much about the health and wellbeing of their environment and ultimately of their larger biomes.

Scientific focus areas like the ENIGMA, funded by DOE's Office of Science Biological and Environmental Research program, enable multidisciplinary research that can investigate microbiome function from the molecular level or an individual organism to the interactions of whole communities of microorganisms in field sites. ENIGMA aims to understand how environmental contamination affects these microbial communities and perhaps one day, identify methods to mitigate contamination. ENIGMA has already led to significant improvement in our understanding of how microbes interact with each other and technologies developed to probe these interactions have been shown to have broad applicability beyond this project, winning R&D100 awards.

Despite the recent explosion in microbiome research, an enormous knowledge gap remains. More research is needed to understand microbiome function, how those functions might be manipulated, and how manipulation of microbiomes can be used for application in energy, environment, and agriculture. To truly interrogate this space, collaboration across many scientific disciplines -- biology, ecology, physics, mathematics, computing -- is required, and national lab capabilities are ripe to address many of the research challenges in microbiome science. Through the manipulation of microbiomes, one can imagine bioenergy crops developed with microbiomes that promote growth and mitigate stressors so that these crops can be grown on marginal lands with minimal fertilizer and water. And one could use tailored microbiomes to remediate contaminated soils, making them amenable to agriculture, construction, or recreation. Microbiome-based fermentation could also be used to convert waste gases such as carbon dioxide and methane that pollute our environment to valuable products. These are just a few applications that could be realized as a consequence of a deeper understanding of microbiome structure and function.

The research and development needed to make progress on all these fronts will require an approach that includes biologists, ecologists, chemists, computer scientists, mathematicians, and statisticians in a coordinated manner. Beyond the scientific questions, new technologies will be needed to manipulate microbiomes and to ensure that findings in the lab are reproducible in the real world. Efforts like the National Microbiome Data Collaborative and the DOE Systems Biology Knowledgebase will be essential for ensuring that microbiome data and analyses can be shared broadly and systematically for development of new products and services. And this can't be done alone- national labs must work with industry, who will commercialize microbiome technologies, and regulators to ensure that applications of microbiome research are safe and provide value to the American public.

2. HIGH PERFORMANCE COMPUTING AND ADVANCED NETWORKING

A revolution is underway - steadily and unmistakably - in many scientific domains and we have reached an inflection point. Scientists are developing new tools to access, manipulate, analyze, combine, and re-purpose complex datasets. At the same time, they are using sophisticated mathematical analyses and simulations to drive the discovery of relationships across datasets. Across many fields of observational and experimental science, data-rich discovery environments are emerging. Assembling these environments takes three ingredients: high performance computing and networking resources for data processing, transfer, storage and analysis; scalable and flexible software tools and applications; and highly skilled experts - including mathematicians, engineers, and computational and domain scientists. Each ingredient is important. When carefully integrated, they can render large-scale datasets that are tractable and useful. Effective discovery environments for extreme-scale data promise many benefits, including more insight per experiment, higher quality results, greater impacts for facilities, and increased democratization of science. New data analysis techniques will enhance, not replace, theory and experiment as techniques for inquiry.

At Berkeley Lab, our vision is the development of a "superfacility" that closely binds user facilities, experiments, and users with HPC computing and advanced networking. This Superfacility will transform science through a network of connected facilities, software, and expertise to enable new modes of discovery. This isn't a brick and mortar facility, but a virtual one that connects assets and squeezes out more knowledge, more efficiencies, and a higher return on the federal investment.

In particular, we envision an experimental facility (such as a DOE Office of Science light source), one or more data management and processing facilities, and the network fabric and software infrastructure to bind them all together as an integrated Superfacility which provides seamless, real-time access to the capabilities of both data source and data analysis facilities as one. An end-user of an experimental facility would operate as though at a single facility, without knowledge that they are actually using multiple DOE user facilities.

As an illustration, a user might begin to conduct an experiment at a light source end station; preparing and placing their experimental sample; tuning the beamline optics and configuring the Data Acquisition (DAQ) system; run QA tests, then the actual science-driven experiment; and see the fully-processed results on their monitor alongside the beamline controls and DAQ -- never realizing that the processed results shown required transfer of data, marshalling of real-time compute resources, execution of a complex analysis chain incorporating advanced mathematics and analytics, and visual presentation of results back to the end-station. Such a user would never need to worry about multiple user accounts and permissions; never need to know about queues and compute architectures; or ever concern herself with inter-process communications or any of the other details of how the processing happens.

Berkeley Lab Computing Sciences, ESnet, NERSC, and the Computational Research Division have begun to partner with DOE experimental facilities, such as the Advanced Light Source, to automate pipelines to run on HPC systems, improve network transfer rates between facilities, create new mathematical techniques for data analysis and develop software tools to aid in the sharing and curation of data.

Unlocking Secrets of Proteins - Never Before Seen Macromolecular Structures

Photon science experiments at facilities such as the ALS, LCLS, and NSLS-II, enable scientists to resolve the structures of macromolecular protein complexes that were previously inaccessible, capture bond information in the elusive transition-state of a chemical reaction, and probe the extreme states of matter. These light sources come with varying numbers of instruments arranged in a tight cluster. Some of the detectors on these instruments now generate terabytes of data per sample. While beamline scientists were once able to carry data home on a flash drive, massive increases in spatial and temporal resolution has lead to increasing data set sizes and the need to look for new solutions for data analysis.

The computational challenge for light source data analyses is to reduce the time to solution from weeks to minutes with real-time interpretation of molecular structure revealed by X-ray diffraction, while dramatically increasing the experimental throughput. For example, the LCLS detector rates will increase 1000-fold by 2025. Recent work with Berkeley Lab's Computational Research Division (CRD), ESnet, NERSC, and ALS along with partnerships with SLAC's LCLS facility has informed what is perhaps a growing trend at DOE Light Sources. If sufficient bandwidth can be provided then a shared high-performance computer, coupled with fast storage, can provide beamline scientists access to large scale resources and faster time to solution. Faster data analysis in practice can mean spotting errors in sample handling or experimental setup, and numerous other issues that can bring beamline progress to a halt and slow scientific discovery.

What to do with the Explosion in Biological Data?

Over the past 2 decades there has been an explosion of biologic data production, and the DOE science-complex has been and will continue to be a major contributor to this data deluge. Berkeley Lab scientists envision using this vast trove of data to solve major problems in energy and environment through the creation of new models of biological function that enable prediction, control and design of biomolecules, microbes, plants, and biomes. This vision requires not just the analysis of large volumes of data, but also the integration of a variety of different kinds of data, spanning -omics, images, and sensors, across time scales from nanoseconds to years.

DOE's leadership in high performance computing positions the national laboratories well to address this challenge, but it is important to recognize that performing biological computing on supercomputers requires significant modification to algorithms and software currently employed for this task, as well as a commitment by supercomputing facilities to understand the needs of the biology community. This will not happen without significant investment in the specific problem of high performance biologic computing and will require the collaborative effort of biologists, bioinfomaticians, applied mathematicians, and computer scientists. Success in this endeavor will have benefits reaching well beyond DOE's mission space to the public sector including health, agriculture, and biomanufacturing industries. This is a hard problem whose benefits justify focusing the national lab complex's expertise and capabilities on it.

Materials by Design with High Performance Computing

Advanced materials are essential to economic and societal development, with applications in multiple industries, from clean energy, to national security, and human welfare. Historically, novel materials exploration has been slow and expensive, taking on average 18 years from concept to commercialization. Traditional empirical and 'one-at-a-time' materials testing is hence unlikely to meet our future materials innovation challenges in a timely manner. However, due to tremendous improvements in computing, coupled with software development during the last decades, real materials properties can now be calculated from quantum mechanics – *much faster than they can be measured.* A new era of computational materials prediction and design has been born.

In 2010, Berkeley Lab saw this opportunity, and by leveraging team expertise in multidisciplinary areas spanning software design, computing, and materials science, created the first open online materials database by enabling thousands of automatic calculations per week – enabling screening and predictions - for both novel solid as well as molecular species with target properties. Since then, the *Materials Project* (www.materialsproject.org) has been constantly computing the properties of all known inorganic materials and beyond, and disseminates the results freely to the public. This 'google of materials' allows students, researchers, and industrial engineers to ask informed questions that translate into 'give me all safe Li-ion battery materials that can run an electric car for 300 miles' and it will produce a long list of structures and chemical systems which have the potential to satisfy the criteria. The current release contains data for over 70,000 materials with millions of associated properties and the numbers grow daily. As a testament to its popularity, the Project has over 45,000 registered users worldwide, and thousands log into the web site every day and use the resource. Several examples of novel materials that were designed using the data and design resources span the breadth of novel waste heat recovery materials, new battery materials, new solar fuel catalysts and new sensor materials, that can enable new industries and new solutions to technological challenges.

3. DRIVING ENERGY SOLUTIONS TO SOCIETY

Basic science forms the foundation that our nation's technology solutions are built on. From that bedrock, the national laboratories have built strong partnerships with industry to move use-inspired technologies out of the lab and closer to commercialization. Berkeley Lab has contributed to the development of many high profile technologies that improve our lives and contribute to the American economy. One example is the class of materials known as "quantum dots" – nanoscopic semiconductor crystals that are finding a wide range of applications today, in everything from QLED TVs, to light bulbs, to biomedical imaging, and more. Berkeley Lab's decades of basic research to explore and improve the useful properties of quantum dots led to a valuable patent portfolio, licensed by U.S.-based companies to commercialize the use of quantum dots in several different fields of use. Emerging applications of quantum dots include targeted cancer therapies and improving solar cell performance. National laboratory researchers working in basic and early-stage applied research provide a steady supply of basic science discoveries that feed into the nation's technology development pipeline. The following examples are just a few of the countless contributions that our researchers have made and are continuing to make to enable the energy technologies of the future.

Saving Billions for American Taxpayers through Energy Efficient Technologies

For more than 50 years, Berkeley Lab has been at the forefront of developing technologies and tools to make buildings and urban infrastructure more energy- and resource-efficient.

Spurred by the energy crisis in the 1970's, Berkeley Lab delved deeply into energy efficiency research, developing many groundbreaking technologies. Particularly impactful is a partnership forged between the Lab, window manufacturers, and the building industry to develop a low-emissivity (low-E), energy-efficient window coating that prevents heat from entering in the summer and escaping in the winter. The technology revolutionized the industry, reducing window energy use by 30-40%. Today, more than half of all residential windows and 80% of commercial windows sold annually have the Low-E coating.

The combined impact of the low-E windows and other Berkeley Lab-developed tools and technologies, including electronic ballasts, simulation software, and appliance standards have saved American consumers more than $484 billion through 2012.

Building on its early research, the Lab continues to drive new innovations in energy efficiency, from individual components to whole building systems. Key to that work is FLEXLAB, the most comprehensive and advanced building efficiency test facility in the world. Used by industry, the public sector, and academia, FLEXLAB allows its users to test energy-efficient building systems individually or as an integrated system, under real-world conditions, ensuring that a building will be as efficient as possible before construction or retrofitting even begins.

With world-leading expertise encompassing lighting, sensors and controls; advanced windows and building envelopes; and simulation and control systems, analytic instruments and computational modeling, Berkeley Lab's uniquely comprehensive portfolio of expertise supports DOE in its mission to develop innovative, cost-effective, energy saving solutions for commercial and residential buildings, ultimately enabling the planning, design, and operation of livable, economically efficient, resilient cities.

Driving Advances in Energy Storage Solutions

Energy storage is critical for American energy independence, and Berkeley Lab has a long and successful history of leveraging its scientific facilities and expertise of its researchers to perform world-class, collaborative battery energy storage R&D. With capabilities in materials synthesis and characterization, theory and computational modeling, and design and failure analysis, Berkeley Lab has been at the forefront of game-changing discoveries that have the potential to transform the battery landscape.

In a recent breakthrough, Berkeley Lab scientists collaborated with Natron Energy and New York University to confirm a century-old chemistry speculation, a finding with broad-reaching implications for the future of battery technology. The researchers took advantage of two Berkeley Lab user facilities, the Advanced Light Source and the Molecular Foundry, to study an unconventional, but promising, new sodium-based battery design. They discovered a key to the battery's superlative properties was a novel chemical state of the element manganese. The revelation could lead to new classes of high-performance, low-cost batteries that can quickly and efficiently store and distribute energy produced by solar panels and wind turbines across the electrical grid.

Another example of basic research moving through the technology development pipeline is a porous membrane technology for better batteries. Membranes are an essential component of batteries, and better membrane performance means higher power, greater cycling time, improved efficiencies, and ultimately lower cost. Berkeley Lab researchers affiliated with the Argonne National Laboratory-led Joint Center for Energy Research (JCESR) DOE Energy Innovation Hub developed membranes for lithium-sulfur batteries made from polymers of intrinsic microporosity (PIMs), utilizing the Molecular Foundry and NERSC user facilities. The promise of this basic research to advance toward commercialization became apparent, and the intellectual property for PIMs membranes was licensed by a local startup company, Sepion, to advance the commercialization of this technology, which has also been recognized with an R&D 100 award. Sepion has received support and technology development assistance through the Cyclotron Road program at Berkeley Lab, ARPA-E, and the Advanced Scientific Computing Research-supported HPC-4MFG program. These programs ensure that the most promising advances in technology development are accelerated to market for the benefit of American manufacturing and consumers.

Lessons from Leaves - Liquid Fuel from the Sun

An example of an emerging technology that has the potential to transform our energy supply in the future is artificial photosynthesis – a chemical process that replicates plant-based photosynthesis to use sunlight to drive the synthesis of a useful chemical, such as a fuel. This nascent field of research holds great promise for supplying our future energy needs, not just on Earth, but could one day also provide future space expeditions a reliable supply of fuel on the Moon or Mars! Berkeley Lab researchers are pioneering this field in partnership with Caltech through the Joint Center for Artificial Photosynthesis (JCAP), a DOE Energy Innovation Hub. JCAP's first phase was focused on so-called "water splitting"—using a catalyst and the energy from sunlight to extract hydrogen from water molecules to create hydrogen fuel. The basic research discoveries made by JCAP researchers about solar-driven hydrogen generation systems have been transferred to the early stage applied research of the EERE-sponsored HydroGEN Energy Materials Network consortium—an example of DOE's pre-competitive R&D for accelerated commercialization. Meanwhile, JCAP researchers have turned their attention to a new, more scientifically challenging goal of discovering how to produce carbon-based transportation fuels—like the ones we use to fuel today's transportation vehicles— from sunlight, water, and carbon dioxide.

Dr. Mary Maxon is the Associate Laboratory Director for Biosciences at Lawrence Berkeley National Laboratory. Berkeley Lab's Associate Laboratory Director for Biosciences (http://biosciences.lbl.gov/) oversees the Biological Systems & Engineering, Environmental Genomics & Systems Biology, and Molecular Biophysics & Integrated Bioimaging Divisions, as well as the DOE Joint Genome Institute. She has been integral to the strategic planning efforts and development of the Area for four years, most recently as the Biosciences Principal Deputy. She received a Ph.D. in molecular cell biology from the University of California, Berkeley. Prior to coming to the Lab, Maxon worked in the biotechnology and pharmaceutical industries, as well as the public sector; this service was highlighted by her tenure as the Assistant Director for Biological Research at the White House Office of Science and Technology Policy in the Executive Office of the President, where she developed the National Bioeconomy Blueprint (https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/national_bioeconomy_blueprint_april_2012.pdf). With her extensive background in industry, scientific foundations, and state and federal government, Maxon is a national leader in science and technology policy. She has helped the Lab develop important initiatives, including Microbes to Biomes, the National Microbiome Initiative, BRAIN, the Agile BioFoundry, and the California Initiative to Advance Precision Medicine.

Chairman SMITH. Thank you, Dr. Maxon.
And, Dr. Kao.

TESTIMONY OF DR. CHI-CHANG KAO, DIRECTOR, STANFORD LINEAR ACCELERATOR CENTER, NATIONAL ACCELERATOR LABORATORY

Dr. KAO. Mr. Chairman——

Chairman SMITH. I still don't think your mic is on.

Dr. KAO. I need to punch it.

Chairman SMITH. There. Okay.

Dr. KAO. Chairman Smith, Ranking Member Johnson, and Members of the Committee, my name is Chi-Chang Kao, the Director of SLAC National Accelerator Laboratory. I'm happy to be here to talk about how SLAC is leading the way of basic research and innovation in the United States.

SLAC, located on the Stanford campus in Menlo Park, California, is one of the ten Office of Science labs. We have an annual research budget of around $300 million with another $280 million in fiscal year 2017 to construct two new large user facilities.

SLAC was established in 1962 as a center of particle physics, as the Chairman described at the beginning. The laboratory has evolved over the last ten years into a multiprogram lab. The focus of the laboratory is on fundamental science, discovery of the things that we don't know about nature. The work has led to four Nobel Prize over the last few decades.

Let me give you two examples. The laboratory today operates two major x-ray facilities. One of them is Stanford Synchrotron Radiation Lightsource. The other one is Linac Coherent Light Source. Linac Coherent Light Source is the world's first x-ray free-electron laser. A free-electron laser is a very different kind of x-ray source. It comes in a very short time, one millionth of a one billionth of a second, the timescale in which electrons move, atoms move. It let us to take snapshots and to make movies of how things actually work in nature.

And after the machine was built in 2009, there was international competition both when Europe and Asia tried to duplicate what we have done. And so there is an LCLS–II project currently ongoing, and then also two high-energy upgrades beyond that. These two projects are made possible because of multi-laboratory collaboration between Fermilab, Argonne National Lab, Berkeley Lab, and SLAC that allowed us to make it happen quickly and have the technology better than our competitors.

And when these two upgrades are completed in the mid-2020 time frame, we will have the world's most powerful x-ray facility available to scientists around the United States for research on materials, chemistry, biology, and applied energy programs. These will lead to better electronics, batteries, new drugs, and also new materials like quantum materials that may be important for quantum computing in the future.

SLAC is also participating in a collaboration between the National Science Foundation and Department of Energy High Energy Physics Office where we are building the Large Synoptic Survey Telescope. This is the largest digital camera made to survey the sky, half of the southern sky every few days. That data will be made available to everyone in the country, even the high school students. They can look at this to understand the mysteries we still don't know about dark matter and dark energy.

And in partnership with DOE, SLAC and Stanford University have developed a new M&O contract. That new contract allows us to streamline processes that we use, and give back autonomy and local control to the laboratory so we can be more efficient and more effective in utilization of the resources that we have.

Finally, in the last 55 years, SLAC has made significant contributions to basic science. Those contributions serve as a basis for the future. The 1,500 staff at SLAC are looking forward to the future so that we can make even more contributions after these facilities are built.

I'm happy to be here today, and thank you for the invitation. I'm looking forward to the questions.

[The prepared statement of Dr. Kao follows:]

Testimony of

Chi-Chang Kao, Ph.D.
Lab Director
SLAC National Accelerator Laboratory

Before the
U.S. House of Representatives Committee on Science, Space, and Technology

March 14, 2018

Chairman Smith, Ranking Member Johnson and Members of the Committee, I'm very pleased to be here today to talk about SLAC National Accelerator Laboratory's unique role in leading basic scientific research and innovation.

I am the director of SLAC, as well as an X-ray scientist with an extensive background in development of X-ray tools for advanced materials research.

SLAC is one of 17 national laboratories operated by the Department of Energy (DOE). As an Office of Science lab, SLAC's focus is on the delivery of scientific discoveries – enabling research leading to four Nobel Prizes – and major scientific user facilities to transform our understanding of nature and to advance the energy, economic, and national security of the United States. Our scientific user facilities are among the most important resources that SLAC and other national labs have to offer because they support the entire U.S. R&D enterprise. These are large, complex facilities with world-class research tools on a scale that no single company or university could afford to build and operate.

SLAC is operated by Stanford University for the DOE Office of Science. Our strong relationship with Stanford provides tremendous advantages in both research and operations. One aspect of this relationship is unique in the DOE national lab complex: DOE and Stanford worked together over the course of a year to develop a new management contract that streamlines many of our standard management processes, eliminates duplication and gives the lab more autonomy and local control, which makes us more efficient and effective. The new contract makes line managers responsible for meeting performance goals and incorporates many Stanford business practices, taking advantage of the university's long experience in operating large research institutions. For example, we have adopted the Stanford cyber security system after demonstrating that it exceeds DOE requirements; this allowed us to improve our cyber security at minimal cost. We are now piloting the new management agreement, and several national labs across the complex have expressed interest in understanding and applying this model.

SLAC was founded in 1962 as a laboratory dedicated to particle physics, using a two-mile-long electron accelerator to probe the smallest building blocks of matter. Today it is a vibrant multi-program lab with 1,500 employees and a research budget of approximately $300 million annually, with another $288 million in FY 2017 funding for major new scientific user facilities and tools. The bulk of our funding comes from the Basic Energy Sciences and High Energy Physics offices within the Office of Science.

With funding from Basic Energy Sciences, SLAC operates two premier X-ray user facilities, the Stanford Synchrotron Radiation Lightsource (SSRL) and the Linac Coherent Light Source (LCLS). These facilities are used by about 2,700 visiting scientists from universities, government labs and industry each year for experiments across a wide range of scientific fields.

SSRL was the first synchrotron X-ray facility in the world to make itself available on a competitive basis to visiting researchers. It's known for the elegant instrumentation it develops to tackle difficult scientific problems, and for its long tradition of giving visiting scientists the expert help they need to make their experiments successful. Work at SSRL was the basis for Roger Kornberg's 2006 Nobel Prize in chemistry for creating the first detailed picture of how instructions in DNA are copied onto messenger RNA, which ferries them to the cellular factories where proteins are made.

LCLS opened in 2009 as the world's first X-ray free-electron laser (XFEL), delivering the brightest and shortest X-ray pulses ever made. Like a camera with an incredibly brilliant flash and ultrafast shutter speed, LCLS allows scientists to make snapshots of chemical reactions and other important processes up to 120 times per second and then string these frames together into "molecular movies," revealing rapid-fire, molecular-scale changes in much finer detail than could ever be seen before. This is important in fields as diverse as the development of catalysts for industry; next-generation energy and computer storage technologies; pharmaceutical drug discovery; and understanding how to harness the properties of quantum materials.

In addition to operating these two X-ray facilities, SLAC researchers carry out world-leading research programs in materials, chemical, biological, plasma, and fusion energy sciences. These research programs operate with funding from the offices of Basic Energy Sciences, Fusion Energy Sciences and Biological and Environmental Research. They aim to answer the most challenging scientific problems within their fields and drive the development of new tools at our scientific user facilities. Optimizing the synergy between the lab's scientific user facilities and research programs enables SLAC to effectively carry out the mission of the Office of Science.

Increasingly, our scientists are also using their expertise and our facilities to work on applied energy science, including batteries, solar energy, and other technology developments aimed at enhancing U.S. competitiveness. They also assist companies with using our facilities to perform research that would be impossible for them to conduct on their own.

For instance, Applied Materials, the world's leading manufacturer of equipment for making semiconductor chips and displays, has been coming to SLAC for more than a decade for help to improve its manufacturing processes; at the other end of the spectrum, startups have used our facilities to analyze and improve materials for solar rechargeable batteries, smart windows and coatings that prevent dirt buildup on solar cells.

With funding from the office of High Energy Physics, SLAC continues to be a major contributor to exploring the frontiers of high-energy physics and cosmology from locations underground, on the Earth's surface, and in space. SLAC is leading an international collaboration that will carry out one of the most sensitive searches ever undertaken for particles of dark matter, which just received construction approval. We are also currently building the world's biggest digital camera for ground-based astronomy for the Large Synoptic Survey Telescope (LSST), which will conduct the widest, fastest and deepest sky survey ever undertaken from the top of a mountain in Chile. The survey, a collaboration between DOE and the National Science Foundation, will dramatically advance our knowledge of the dark energy and dark matter that make up 95 percent of the universe, as well as of galaxy formation and potentially hazardous asteroids. SLAC also makes significant contributions to the ATLAS experiment at Europe's Large Hadron Collider, where scientists continue to explore the properties of the Higgs boson and look for signs of new physics that will enhance our limited understanding of the physical world around us.

In the following, I would like to give you just a few examples that highlight the impact of SLAC research.

- New materials are critical for advances in many areas, from batteries and electronics to lighter, stronger structural components for cars, planes and other uses. Studies of materials at SLAC range from addressing here-and-now problems – for instance, working with industry to prevent flaws in metal parts made with 3-D printing – to fundamental studies of "quantum materials" and electron behavior that could lead to the creation of denser, faster circuits and entirely new methods for storing and processing information.

  To try to understand how electrons behave when confined in an extremely limited space, SLAC researchers have studied the thinnest possible layers – sheets of matter from just one to a few atoms thick. Using SLAC's unique suite of X-ray tools and related capabilities, researchers have been able to determine how electrons in these sheets respond on ultrafast time scales, in the range of millionths of a billionth of a second. Understanding this extremely rapid response is crucial for achieving the highest possible rates of information processing and is key for the advancement of information technology.

- Catalysts are specially designed materials that promote chemical reactions without themselves being consumed in the process. They're a vital part of industrial processes that underpin about a third of the nation's GDP, from cracking crude oil to make gasoline to producing the fertilizer needed to feed a rapidly increasing global population.

At SLAC, scientists lead the world in using theory and advanced computation to predict the best catalysts for targeted chemical reactions, and use X-ray beams and other experimental tools to watch catalytic reactions unfold at an atomic level under realistic industrial conditions. By combining theory and experiment, they are able to find new catalysts and make the ones we have today more efficient.

An important problem being investigated at SLAC is the identification of catalysts for the efficient transformation of natural gas, or methane, into easily transported liquid fuels like ethanol. SLAC scientists are also collaborating with researchers from Chevron and other oil companies to use SSRL X-rays to improve the performance of their industrial catalysts.

- In biology, X-rays reveal how proteins – workhorse molecules in all living things – function in our bodies and in nature. This gives scientists a better understanding of how disease develops so they can design tailor-made vaccines and medications. Pharmaceutical companies have come to SSRL for decades to investigate basic biological processes and test potential drug candidates; this work has contributed to the development of Tamiflu and treatments for melanoma, HIV and other diseases.

The National Institutes of Health have been an important partner in this research for decades, supporting the development of X-ray equipment and other instruments at SSRL and more recently at LCLS, where about one-third of experimental time is now devoted to bioscience.

In one LCLS study, experimenters recently discovered that a hormone receptor on the surface of human cells may be a good target for new medications related to cardiovascular conditions, neuropathic pain, inflammation, and tissue growth. This receptor receives signals from a hormone that helps regulate blood pressure, but its exact structure and function have been a mystery for decades. More than half of all the medications on the market today are aimed at blocking or activating receptors like this one that sit in the cell's outer membrane, but in the past it's been difficult to form them into large enough crystals for synchrotron X-ray studies to determine their structure. With LCLS X-ray pulses, the scientists were able to get the structure of the receptor from much smaller nanocrystals that are significantly easier to prepare. This capability opens up many new possibilities for developing medications to target a large number of membrane-embedded receptors that were previously out of reach.

The success of LCLS inspired countries around the world to plan or build their own X-ray free-electron lasers. XFELs have opened for experiments in Japan, Europe, South Korea and Switzerland. China is close behind, with plans to build an XFEL in Shanghai.

With this in mind, SLAC is constructing a major upgrade to LCLS in partnership with four other national labs and a university. This project, called LCLS-II, is scheduled to open in the early 2020s. It will significantly boost the power and capacity of the X-ray laser, adding a second X-ray laser beam that fires up to a million pulses per second and shines 10,000 times brighter, on average, than the one we have now.

This extraordinary pulse rate is by far the highest in the world, and it opens up entirely new possibilities for measuring systems as they are in nature, where things often fluctuate and vary from place to place. It will also provide the very high brightness needed to analyze materials and track chemical changes with exquisite resolution.

To make sure that America stays at the forefront of this vital technology, the Office of Basic Energy Sciences is also planning for the construction of a natural extension to LCLS-II known as LCLS-II-HE (for "high energy"). It would take advantage of the extensive infrastructure that is now in place for building LCLS-II to deliver a major leap in performance to the broadest possible cross-section of scientific users for the least possible additional investment. For instance, it will provide more power in the form of high-energy X-rays, addressing the needs of the 75 percent of our current user community who use this part of the X-ray spectrum in their experiments.

We are grateful for the work of this Committee, which advanced the recently passed HR 4376, the Department of Energy Research Infrastructure Act of 2018, authorizing funding for the LCLS-II-HE project. We are also pleased that the President's FY 2019 Budget Request includes initial funding for this vital project.

With LCLS, we demonstrated that we can observe fundamental processes at atomic resolution and watch them evolve at a rate of 120 frames per second. LCLS-II will allow us to increase this rate to 1 million frames per second, so we can see how electrons move from one place to another during chemical reactions. LCLS-II-HE will extend that high pulse rate to the realm of individual atoms, so for the first time we'll have all three of the capabilities we're looking for: the ability to take snapshots with atomic resolution up to a million times per second while watching individual electrons go about their work.

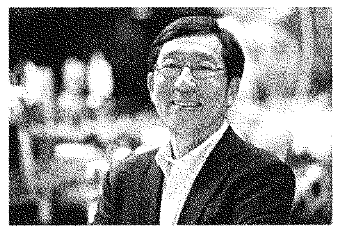
These advances will be truly revolutionary, allowing us to watch chemistry and biology in action, fine-tune catalysts for industry, understand how materials function at a much deeper level and exploit quantum phenomena for future generations of devices in ways that cannot be done today.

In closing, I would like to thank the Committee for inviting me here today, and I look forward to your questions.

SLAC NATIONAL ACCELERATOR LABORATORY

Chi-Chang Kao

Director
SLAC National Accelerator Laboratory



SLAC Director Chi-Chang Kao, a noted X-ray scientist, came to SLAC in 2010 to serve as associate laboratory director for the Stanford Synchrotron Radiation Lightsource. He became SLAC's fifth director in November 2012.

Previously, Kao served for five years as chairperson of the National Synchrotron Light Source at Brookhaven National Laboratory in New York. He undertook major upgrades to the light source's scientific programs and experimental facilities while developing potential science programs for NSLS-II, one of the newest and most advanced synchrotron facilities in the world. His research focuses on X-ray physics, superconductivity, magnetic materials and the properties of materials under high pressure.

Kao earned a bachelor's degree in chemical engineering in 1980 from National Taiwan University and a doctorate in chemical engineering from Cornell University in 1988. He joined Brookhaven shortly afterward, working his way from NSLS postdoctoral research assistant to chair. Kao also served as an adjunct professor in the Department of Physics and Astronomy at Stony Brook University.

He was elected a fellow of the American Physical Society in 2006 and was named a fellow of the American Association for the Advancement of Science in 2010 for his many contributions to resonant elastic and inelastic X-ray scattering techniques and their application to materials physics, as well as for his leadership at the NSLS.

Chairman SMITH. And thank you, Dr. Kao.
And Dr. Kearns.

TESTIMONY OF DR. PAUL KEARNS, DIRECTOR, ARGONNE NATIONAL LABORATORY

Dr. KEARNS. Chairman Smith and Ranking Member Johnson and Members of the Committee, thank you for the opportunity to appear before you. It's my honor to join my colleagues from Idaho, Lawrence Berkeley, Sandia, and SLAC to speak about the national laboratories and the world-leading innovation they deliver.

I am Paul Kearns, Director of your Argonne National Laboratory. Argonne is managed by UChicago Argonne, LLC for the DOE Office of Science. At Argonne, our research pushes the boundaries of fundamental and applied science to solve complex challenges and develop useful technologies that transform the marketplace and change the world.

In fiscal year 2017, Argonne employed 3,200 people in the Chicago area. Our budget was $751 million with approximately 80 percent of the funds from DOE and the balance from the Department of Homeland Security, other government agencies, and the private sector.

Argonne's major strategic initiatives are targeted to deliver breakthroughs in science and technology in areas that support DOE's mission and reflect our vision for the future. They include hard x-ray sciences, advanced computing, materials and chemistry, manufacturing and science, and the fundamental study of the universe. Our unique scientific facilities include a world-leading x-ray source, particle accelerator, supercomputers, and a nanoscience—a nanoscale science center.

As the nexus for thousands of visiting researchers and collaborators, these facilities extend Argonne's impact beyond our own laboratory. At the Advanced Photon Source national user facility we use hard x-rays to characterize materials at the atomic and molecular level to understand, predict, and control their properties. The APS is helping Argonne make additive manufacturing more reliable and hypersonic flight possible. One of the most successful drugs used to stop the progression of the HIV virus into AIDS got started at the Advanced Photon Source.

The Advanced Photon Source upgrade will create a world-leading ultimate 3–D x-ray microscope, enabling researchers to observe individual atoms interacting in real time. This new microscope will make it possible to see changes at the molecular level such as before a steel girder starts to crack, before a healthy brain succumbs to Alzheimer's, and before an electric car's battery begins to fail.

At the Argonne Leadership Computing Facility, two of our supercomputers are among the 20 fastest in the world. We've applied our high-performance computing to challenges in energy, materials, extreme weather, and more. The ALCF is part of the multi-lab initiative with the National Cancer Institute and the Department of Veterans Affairs to apply big data and artificial intelligence to health care and genomic data to determine optimal treatments, improve outcomes, and reduce cost.

In 2021, ALCF will welcome Aurora, an exascale system that will be at least 50 times faster than the most powerful supercomputers in use today. Argonne's efforts in exascale are part of DOE's larger exascale computing initiative.

Argonne's knowledge and facilities, coupled with our approach to deploying these assets, distinguishes us as an institution. We work across the continuum from basic discovery to use-inspired to translational science in order to deliver positive societal impact. Conventional wisdom states that translating scientific advances and impact is a decades-long process. The national laboratories, as you've heard today, have long worked to accelerate this process by enabling researchers to execute more experiments in the same amount of time.

Advanced computing in the form of deep learning, machine learning, and artificial intelligence is providing a powerful new boost to the speed of discovery. Argonne's energy storage work, dating to the 1960s, is an excellent discovery-to-impact model upon which to build.

In the mid-1990s, the DOE supported investigations aimed at a more stable and greater capacity electric vehicle battery. In 2000, we patented our signature battery cell technology, and in 2007 began licensing it for mass production. In 2011, our technology made its market debut in the Chevy Volt.

When it comes to next-generation batteries, the Joint Center for Energy Storage Research, JCESR as we love to call it, which is led by Argonne partnered with 20 other entities, has literally and figuratively changed the formula. JCESR has yielded revolutionary new battery materials in an operations model to optimize entities from many sectors working together.

We're taking our storage—energy storage experience to new frontiers, including catalysis, materials for clean water. We're also working on quantum materials with—which promises nothing short of a revolution in computing speed and accuracy. Argonne and the University of Chicago have set up the QUANTUMFACTORY, an experimental facility, and have collaborated with Fermi National Accelerator Laboratory on the Chicago Quantum Exchange to enable graduate students to learn from national laboratory scientists and academics.

America's national laboratories are powerhouses of science and technology. My fellow Laboratory Directors and I appreciate this Committee's continued support for the national laboratory system and your commitment to leadership in science and technology. Our national laboratory infrastructure is the envy of the world. The DOE and its laboratories are advancing projects that will keep the United States at the forefront of innovation for decades to come.

Lastly, before I close, I'd like to thank this Committee for its leadership in advancing legislation through the House of Representatives to improve and update critical science infrastructure across the national laboratory complex including H.R. 4377, the *Accelerating Americans Leadership in Science Act*, which, among other important priorities, authorizes funding for the APS upgrade project.

Thank you for your time, and I welcome your questions.

[The prepared statement of Dr. Kearns follows:]

Written Testimony of Dr. Paul Kearns

Director, Argonne National Laboratory

before the

Committee on Science, Space, and Technology of the U.S. House of Representatives

March 14, 2018

Chairman Smith and Ranking Member Johnson, and members of the committee, thank you for the opportunity to appear before you. It is my honor to speak about the national laboratories and our world leading innovation in science.

I am Paul Kearns, director of Argonne National Laboratory, one of America's first and largest multipurpose science and engineering laboratories, located in Lemont, Illinois, near Chicago. Before becoming Argonne's interim director in January 2017 and director last November, I served for seven years as Argonne's Chief Operations Officer. Prior to Argonne, I held leadership positions at Battelle Global Laboratory Operations, Idaho National Engineering and Environmental Laboratory, and Pacific Northwest National Laboratory. I also served as a visiting professor in engineering and physical sciences at the University of Manchester in the United Kingdom.

I have dedicated my career to expanding the impact the national laboratories deliver through their unique mission of securing our nation and encouraging break-through discoveries in science and technology. It was the special mission of the laboratories that attracted me to the national laboratory system and it is the opportunity to work with such dedicated and talented people, on matters of immense global scale and impact that has kept me involved with the national laboratories.

Argonne is managed by UChicago Argonne, LLC for the U.S. Department of Energy (DOE) Office of Science. We are one of the 17 DOE national laboratories that together form a productive, world-leading research system. At Argonne, we pursue big, ambitious ideas that redefine what is possible. Our research pushes the boundaries of fundamental science, applied science, and engineering to solve complex challenges and develop useful technologies that can transform the marketplace and change the world.

Argonne traces its beginnings to experiments by the renowned physicist Enrico Fermi, who led researchers in creating the world's first self-sustaining nuclear reaction. From its initial mission to fulfill the promise of the atom as a new energy source, Argonne has continuously built upon and expanded its capabilities. We have grown into a multi-program laboratory addressing a range of major scientific and societal needs. In fiscal year 2017, we employed 3,200 people in the Chicago area, drawn from scores of scientific, technical, administrative, and operations fields, provided national scientific user facilities that supported 8,300 researchers, and hosted another 1,100 visiting research collaborators. Our fiscal year 2017 budget was $751 million, with approximately 80% of funds from DOE and the balance from the Department of Homeland Security, other government agencies, and the private sector.

At Argonne, our primary mission to deliver lasting impact to society. We believe in the vision that our science changes the world. Over the last seven decades, Argonne researchers have built the nation's first high-energy physics user facility, helped found quantum computing, led high-temperature superconductor research, developed an artificial leaf, invented molecular modeling, and much more. Argonne was home to three winners of Nobel Prize for Physics: Alexei Abrikosov (2003), for theories on superconductivity and superfluidity; Maria Goeppert-Mayer (1963) for explaining the shell structure of the atomic nucleus; and Fermi, who received the prize in 1938 for work on induced radioactivity by neutron bombardment and the discovery of transuranic elements, prior to his breakthrough that would mark Argonne's beginning. Building on that proud history of discovery and innovation, we will be known for our ideas and for safely delivering lasting impact on society through our exemplary research and operations.

Argonne's work now spans the spectrum from basic research to applied science in areas including discovery in materials, chemistry, physics, and biology, engineering of advanced energy systems, and computation and analysis. Argonne remains on the cutting edge as it extends its expertise into new scientific frontiers including synthesis science, quantum information science, neuromorphic computing, and catalysis.

In addition to our capabilities, Argonne is committed to delivering high impact science and building foundations for technologies that will shape our nation's future. Our major strategic initiatives are interdisciplinary, highly synergistic with one another and leverage the strengths of our broader research and development (R&D) enterprise. The laboratory's major initiatives build on our distinguishing capabilities in science, unique user facilities, and external collaboration networks and are targeted to deliver breakthroughs in science and technology in five areas that support DOE's missions and reflect our vision for the future. They include:

- Hard X-ray sciences
- Advanced computing
- Materials and chemistry
- Manufacturing science
- Fundamental study of the universe

Propelling Research through Our Scientific User Facilities

Our unique suite of scientific facilities includes a world-leading X-ray source, particle accelerator, supercomputers, a nanoscale science center, and the world's largest atmospheric research field site. These facilities expand our fundamental understanding of matter, materials, and their properties. As a nexus for 8,300 researchers, and 1,100 visiting research collaborators, in addition to our own 1,600 scientists and engineers, these facilities extend Argonne's impact well beyond our own laboratory.

- At the Advanced Photon Source (APS), we use hard X-rays to characterize materials at the atomic and molecular level so that we may understand, predict, and ultimately control the materials' properties. The intense X-rays of the APS helped Argonne design a leading battery cell technology and is helping us make additive manufacturing more reliable, internal combustion engines more efficient, and hypersonic flight more possible. The APS, funded by the Office of Science Basic Energy Sciences program, continues to have high impact in biosciences and drug discovery. As an example, Kaletra®, one of the most successful drugs used to stop the progression of the HIV virus into AIDS, got its start at the Advanced Photon Source; visiting scientists from Abbott Laboratories used x-ray crystallography techniques to pinpoint how the atoms of the drug interact with the viral protein. Recipients of the 2009 and 2012 Nobel Prizes in Chemistry conducted portions of their prize winning work at the APS.

- At the Argonne Leadership Computing Facility (ALCF), we run two supercomputers that are among the 20 fastest in the world. More than 30 of the 500 fastest supercomputers in the world can be found at DOE laboratories, funded by the Advanced Scientific Computing Research program of the Office of Science. At Argonne, we have applied our high-performance computing to challenges in energy, materials, extreme weather, medicine and more, with techniques such as simulations of more efficient jet engines and wind turbines. The Argonne Leadership Computing Facility leads a multi-laboratory team as part of the federal Precision Medicine Initiative with the National Cancer Institute (NCI) and plays a role in the MVP-CHAMPION initiative of the Department of Veterans Affairs (VA) and DOE. These collaborations are applying the labs' big data, artificial intelligence, and high performance computing capabilities to healthcare and genomic data to determine optimal treatment strategies, improve healthcare outcomes, and reduce costs.

- At our Center for Nanoscale Materials (CNM), we apply world-class capabilities in large scale synthesis, nanofabrication, massive parallel characterization, and computational materials discovery under one roof. Funding by the Office of Science Basic Energy Sciences program, CNM is one of five Nanoscience Research Centers (NSRCs) across the nation, first authorized by Congress a decade ago as part of the National Nanotechnology Initiative. As my colleague Supratik Guha, Director of CNM, testified before you last year, these NSRCs are a force in the quantum materials revolution that will enable technologies to transform everything from national security to drug design to data analytics.

- Argonne's Tandem Linac Accelerator System (ATLAS), funded by the Office of Science Nuclear Physics Program, is a leading facility for nuclear structure research in the United States. It provides a large community of users with a wide range of beams for nuclear reaction and structure research, as they probe astrophysical processes generating the chemical elements and test nature's fundamental symmetries and interactions.

- The Atmospheric Radiation Measurement Climate Research Facility – Southern Great Plains (ARM-SGP) is the world's largest and most extensive atmospheric research field site, located in Oklahoma. Funded by the Office of Science Biological and Environmental Research program, ARM-SGP instruments are arrayed across 9,000 square miles, with a heavily instrumented central facility on 160 acres near Lamont, Oklahoma. Scientists from Argonne and other institutions use data from ARM-SGP to advance scientific understanding of cloud, aerosol, and atmospheric processes, which supports improvements in models of the earth's climate.

Staking a Unique Approach to Science

Argonne's broad and deep domain knowledge and scientific facilities, coupled with our approach to deploying these assets for maximum benefit, distinguishes us as an institution. Argonne works across the continuum of science from basic, curiosity-driven efforts, to use-inspired science solving problems of global significance, to translation science in order to deliver meaningful societal impact consistent with our mission. This approach enables us to accelerate progress in science from discovery to impact. We are looking at ways to multiply the beneficiaries of the laboratory's knowledge across the many domains in which we work.

Science, simply put, is the pursuit of knowledge through systematic study executed via observation and experiment. It encompasses pursuits driven by curiosity: What happened immediately after the Big Bang leading to the creation of the known universe? Science also includes pursuits to solve problems: How can we make the U.S. power grid more resilient? At Argonne, we focus on asking the right questions that lead to developing knowledge that can result in positive change in the world.

The problems we work on are inherently multi-disciplinary, stemming from our roots in the Manhattan project, and bring together teams of talented scientists and engineers with relevant technical-domain expertise to work closely, leveraging our cutting-edge analytical capabilities, such as the APS and ALCF. Science is also an inherently collaborative activity. The laboratory works closely with other national labs, universities and with industry in the pursuit and application of new knowledge. Working with industry makes us smarter about practical solutions and enables our scientists and engineers to work with more relevance in the lab's core mission. This also provides the laboratory with more avenues for creating impact from the translation of our science to societal benefits.

Conventional wisdom states that the translational of advances in science to impact is a decades-long process. At the national laboratories, we have worked hard on accelerating this process from scientific discovery to impact by accelerating the speed with which researchers can execute experiments and simulations—for example, high throughput methods for analytical characterization and faster computers. Most recently, however, the laboratory's focus has shifted to the emerging paradigm in computing related to deep learning, machine learning and artificial intelligence. Through the use of these methods, scientists are now accelerating our learning process by using computers to enhance human insights. These advances have the potential to change a process that previously took decades to one that may take only a fraction of that time in the future.

Leveraging Our Discoveries for Transformational Impact

Our world-renowned work in energy storage serves as an excellent example of turning discovery into impact, and an achievement on which we hope to build as we endeavor to accelerate that discovery-to-impact process. Argonne's legacy of energy storage research dates to the 1960s. In the mid-1990s, the DOE provided sustained support for investigations aimed at a more stable and greater capacity electric vehicle battery. In 2000, the original lithium-rich Nickel-Manganese-Cobalt (NMC) blended cathode structure for which we are now known was patented; 2007 saw the beginning of worldwide licensing agreements with Argonne by companies including BASF, Toda America, and LG Chem, who now mass produce and market Argonne's patented materials for advanced batteries. In 2011, Argonne's technology made its market debut in the Chevy Volt.

Argonne also is utilizing basic science approaches as part of the Joint Center for Energy Storage Research (JCESR), DOE's battery and energy storage hub, to understand mechanisms and discover new paradigms for storing energy. JCESR has literally and figuratively changed the formula for developing next-generation batteries. Experiments with new battery materials at the bench have resulted in the discovery of revolutionary new materials for development of beyond-lithium-ion technologies.

The JCESR Operations Model, meanwhile, has integrated and amplified the effectiveness of 20 otherwise independent interdisciplinary scientific organizations – universities, industry, and national laboratories – as a single coordinated unit. This new paradigm for public-private partnership has enabled more than 200 researchers to magnify their efforts and achievements in discovery science, materials design, battery design, research prototyping, and manufacturing collaboration.

Our experience with JCESR has cultivated a new archetype of basic science leading ultimately to proof of concept, a model we are applying to various aspects of our Materials and Chemistry Strategic Initiative, including quantum information, catalysis, and new materials to address energy-water interdependence. In quantum information science, recent developments raise the prospects of a new, rapidly emerging computing architecture. Quantum offers unprecedented speed and efficiency advantages over conventional computing that can be applied to big challenges like exactly solving the electronic structure of large molecules. By enabling us to predict and invent new materials much quicker and more cheaply instead of relying upon trial and error experimentation, as we do today, our potential for progress in areas such as drug discovery are enormous.

Quantum computing also has big implications for cryptography—a quantum computer with its orders of magnitude advantage in speed would easily decrypt today's security codes—and in complex data analytics, where problems like large-scale traffic congestion routing problems can be resolved with unprecedented efficiency. Unique equipment developed at Argonne for research in nanomaterials, such as synchrotron based x-ray microscopy, is being used to "see" exquisitely small distortions in crystals used for building quantum bits.

Partnerships with the University of Chicago aim to fuel progress in quantum information. We have worked together to set up at the laboratory the "Quantum Factory," a comprehensive experimental facility for the synthesis of quantum materials with atomic layer precision. The University and Argonne also have collaborated with the Fermi National Accelerator Laboratory on the Chicago Quantum Exchange, which will develop a new generation of graduate students who will learn their skills in close collaboration with national laboratory scientists and academics.

With regard to catalysis—that is, the acceleration of a chemical reaction by a catalyst—Argonne aims to improve basic understanding of catalytic chemistry in the atomic to nanoscale level. Our research is ultimately focused on developing new catalysts for energy applications. The optimally efficient way to store energy is in chemical bonds, and our future research will be targeted to understand and develop new concepts for making and breaking those bonds when splitting water, reducing carbon dioxide, and adding new functions and capabilities to the carbon-hydrogen bonds found in natural gas.

The looming societal water crisis, together with the techno-economic implications of energy-water interdependence, has highlighted a need for new materials to improve the safety and efficient use of water. Argonne is working to devise effective new membranes, sorbents, sensors, catalysts, surface treatments, and coatings tailored for specific functions such as resisting the fouling of pipes and underwater surfaces by organisms like barnacles and algae.

Like the new directions we are pursuing in quantum information science, Argonne's new goals in catalysis and energy-water interdependence are grounded in collaboration among Argonne's own scientists specializing in nanoscience and technology, biology, chemical sciences and engineering, materials science, and molecular engineering. They are also supported by new external partnerships including the Institute for Molecular Engineering (IME) with the University of Chicago and the Northwestern (University)-Argonne Institute for Science and Engineering (NAISE).

Thriving on Partnership

The national labs are indeed at their best when they are working as part of an innovation ecosystem with academic, industrial, and entrepreneurial partners. In the realm of industry, laboratories have relevant capability, expertise, and nascent technology to "de-risk" innovations and accelerate commercialization. Through our Cooperative Research and Development Agreements and Strategic Partnership Projects, we provide mechanisms for companies to collaborate with national laboratories, and enable them to directly sponsor research and development at the labs.

Argonne is home to other unique programs that continue to expand our industrial relationships and efforts to help commercialize promising technology. Chain Reaction Innovations provides energy entrepreneurs with the laboratory tools, seed capital, and collaborators needed to grow and attract the long-term capital and commercial partners needed to scale and launch into the marketplace. The first cohort teams have raised $400,000 in external funding, including grants, prize money, and investments, and have also partnered with industry and developed prototypes; soon we will name the second cohort of entrepreneurs to the program. Argonne also participates in DOE's Executive in Residence Program, which allows company-employed scientists to work with laboratory senior technical staff during the later stages of technical development.

The Argonne Collaborative Center for Energy Storage Science, or ACCESS, and Argonne Design Works are other methods for extending our domain knowledge to industry, offering a concierge approach to pulling together exactly the expertise needed for a particular innovation. In addition, Argonne works with various federal agencies in a wide range of areas, including transportation, security, grid innovation, and the physical sciences, and is collaborating with municipalities including Chicago and Detroit on complex systems modeling and data-driven decision-making tools to improve efficiency, resiliency, sustainability and foster economic growth.

Forging New Directions

At Argonne, we are charting a course for the next horizon in U.S. scientific leadership through our major initiatives, drawing on our foundational strengths and leveraging our ever-expanding expertise to transform Argonne's contributions to discovery and innovation and produce breakthroughs that will change our nation and our world for the better.

Our Hard X-ray Sciences Initiative include a highly cost-effective revitalization of the facility, improving capabilities by orders of magnitude, maintaining our competitive advantage over other nations, and keeping the U.S. at the forefront of hard x-ray science for decades to come. The APS Upgrade will create the ultimate 3-D microscope, produce the world's brightest hard x-rays and transform our ability to understand and manipulate matter at the nanoscale. With this powerful, versatile tool, researchers will be able to observe individual atoms moving and interacting – in real time – deep inside real samples, biological organisms and complex engineered systems. This new microscope will make it possible to see changes at the molecular level that occur before a steel girder starts to crack, before a healthy brain succumbs to Alzheimer's, and before an electric car's battery begins to fail. We very much appreciate this Committee's strong support for the APS and its leadership in passing H.R. 4377, The Accelerating American Leadership in Science Act, out of the House of Representatives, authorizing funding to upgrade the facility. Additionally, we are very pleased the fiscal year (FY) 2019 President's Budget Request includes funding for the APS Upgrade and transitions the project to a separate line item construction project.

In our Advanced Computing Initiative, we look forward to the Argonne Leadership Computing Facility being the future home of Aurora, an exascale system will be at least 50 times faster than the nation's most powerful supercomputers in use today. Scheduled for deployment in 2021, the Aurora system is being developed by Intel in partnership with Cray and will be the first generation of a new architectural direction targeted at broad application performance with exceptional performance and energy efficiency. At the same time, Argonne researchers are developing new capabilities in machine learning and artificial intelligence—and looking beyond conventional computing technology to develop systems, algorithms, and applications based on new quantum and neuromorphic technologies—all as means to helping overcome the nation's biggest challenges in energy, materials, cancer and more.

Argonne's efforts in exascale are part of the larger push of the Exascale Computing Initiative (ECI), a collaboration of the DOE Office of Science, the National Nuclear Security Administration and six national laboratories. This collaboration aims to develop and deploy capable exascale systems with rich software environments and mission-critical application code, advance the integration of simulation, deep learning, and data capabilities into exascale platforms. Thank you to this Committee for your strong support of exascale and next generation computing. We are pleased that the FY2019 President's Budget Request also includes funding for ECI and advancing one of the nation's first exascale machines at Argonne.

Our Materials and Chemistry Initiative and its concentrations on energy storage, catalysis, quantum information, and energy-water interdependence will be elevated by our Materials Design Laboratory. In this state-of-the-art facility, researchers investigate structures at scales all the way from a single electron on up, study the interfaces where molecules come together in new materials, and test the properties of these materials under extreme conditions. The Materials Design Laboratory will be the final building to complete Argonne's Energy Quad—four adjoining buildings where energy and materials scientists can maximize their collaboration with one another and with partners from outside the lab.

In our initiative for fundamental study of the universe, known as Universe as Our Lab, we will be pioneering techniques to simulate the universe and detect elementary particles. We will drive advances in the measurement of cosmic microwave background radiation and develop forefront superconducting transition-edge sensor technology for particle and nuclear physics experiments.

Our Manufacturing Science and Engineering Initiative aims to boost industrial success in producing innovative materials for future energy technologies. Revolutionary energy technologies, which are essential to future American prosperity, will require efficient and scalable manufacturing of innovative devices based on new materials and chemistries. Our goal is to accelerate the progression from discovery to manufacturing demonstration by defining the scientific and engineering basis for scalable manufacturing of energy storage and transfer devices and exploring new manufacturing methods.

Continuing Support for U.S. Leadership in Science

America's national laboratories and their facilities are powerhouses of science, technology, and engineering. They are principal agents of execution on missions of national importance. Critical to the DOE mission of solving big problems in energy and national security, the labs attract some 30,000 users a year from government, industry and academia from all 50 states. Labs provide value at all points of a science and technology development cycle—not only seeding the gradual growth of new ideas but also reverse engineering to stabilize and improve ideas as they emerge in the market.

My fellow laboratory directors and I greatly appreciate this Committee's continued support for the national laboratory system and commitment to U.S. leadership in science and technology that is critical for our future. International competition remains as fierce as ever; our science infrastructure across the nation is the envy of the world, with many countries trying to replicate it. The DOE and its laboratories are advancing projects that will keep the U.S. at the forefront of science and innovation, with an aim to cement U.S. leadership for decades to come.

From longer lasting, faster charging vehicle batteries to personalized medical treatment, DOE labs and their one-of-a-kind facilities offer unparalleled scientific capabilities that have real societal impact. At Argonne, we are privileged to bring to bear decades of expertise in physics, materials and chemistry, math and computer science, life sciences, nuclear energy and more to help provide greater security and prosperity to Americans.

Thank you for your time. I welcome any questions you may have.

Paul K. Kearns is the director of the U.S. Department of Energy's Argonne National Laboratory. He is responsible for guiding development and implementation of the laboratory's strategic vision and leading Argonne to deliver outstanding performance in science and technology, operations, employee health and safety, and environmental protection. Dr. Kearns promotes a culture of innovation and collaboration within the laboratory and helps Argonne maintain strong strategic partnerships.

Dr. Kearns has nearly three decades of management experience, a strong background in science and engineering and extensive experience with the U.S. Department of Energy. He served six years as Chief Operations Officer for Argonne.

Dr. Kearns came to Argonne from Battelle Global Laboratory Operations, where he conducted strategic planning and business development for research activities in energy, environment, and national security and led an initiative to deliver greater value to government and commercial energy clients through enhanced national laboratory collaboration. With Battelle he also led an analysis of research and development and investment strategies in nuclear energy for the U.S. Department of Energy and the United Kingdom Technical Strategy Board; established a Joint Capability Technology Demonstration on micro-grids and supporting cyber security for the U.S. Pacific Command; and served as president and managing director of a subsidiary founded to help Italian government and industry solve challenges in energy, security and environment.

From 2003 to 2005 Dr. Kearns was director of the Idaho National Engineering and Environmental Laboratory, where he also served as deputy laboratory director and associate laboratory director for Environmental Technology and Engineering. At Pacific Northwest National Laboratory, Dr. Kearns managed Process Technology and Environmental Management Resources and the laboratory's Waste Disposal Integration Team. For the Department of Energy, Dr. Kearns served in leadership and advisory roles in the Office of Energy Management in Washington and regional offices including the Chicago Operations Office.

Dr. Kearns is a fellow of the American Association for the Advancement of Science, member of the American Nuclear Society and the Society for Conservation Biology, and served as a visiting professor in engineering and physical sciences at the University of Manchester in the United Kingdom. He holds a doctorate and a master's degree in bionucleonics and bachelor's degree in natural resources and environmental sciences, all from Purdue University.

Chairman SMITH. Thank you, Dr. Kearns. I recognize myself for questions, and let me address my first one to Dr. Peters. Dr. Peters, in your prepared testimony, you expressed some concern that the national labs are losing their position as trusted advisors to the Department of Energy. What steps is DOE taking to maximize the effectiveness of labs in your opinion?

Dr. PETERS. Thank you, Mr. Chairman. The Department has reengaged us as a group in a really meaningful way. It's—as I said in my summary, it started with Secretary Moniz, and it's continued with Secretary Perry and his team. So we're—we have active nearly day-to-day engagement with them on aspects related to how we operate the laboratories but also more importantly the strategic directions of the Department, and particularly now with the Under Secretaries in place, there's a lot of back-and-fourth about research priorities and whatnot, so I think we would collectively say the partnership is headed in a very positive direction.

Chairman SMITH. Okay. Good. Thank you.

And, Dr. Kearns, we talked about this earlier today, but you mentioned that JCESR's goal is to develop next-generation batteries that deliver five times the energy at 1/5 the cost. I think we all know that the key to success for encouraging the use of alternative fuels and energy is a better battery, a more efficient battery, a lighter battery, and a battery with greater storage. And when we have that breakthrough, we'll, I think, change the energy world. How close are we to developing that kind of battery, the kind of battery that you've been working on, the five times energy at 1/5 the cost?

Dr. KEARNS. Progress has been substantial. Significant progress is being made. I'm happy to report that by working with our colleagues from four of the other national laboratories and five universities, along with the members, representatives if you will from industry, we've made good progress in terms of the discovery of new materials that are less expensive. They do allow greater energy storage, energy density to be stored and will last much longer, so significant progress is being made.

We've achieved the cost objectives that we talked about in terms of five times less expensive, in terms of the materials that have been discovered through JCESR. We've made good progress as well in terms of energy density, the developments applied to both grid and transportation if you will, storage technologies. I'd also report that we've had three spinout companies, technologies that people have come and taken a look or perhaps helped us develop and then taken to—really into the innovation pipeline to really result in commercial-scale products, so progress has been good.

Chairman SMITH. Okay. Would you want to hazard a guess when such a battery would be commercially available?

Dr. KEARNS. I'm afraid—well, I don't think I can really guess that.

Chairman SMITH. How about an order of magnitude——

Dr. KEARNS. Okay. Okay.

Chairman SMITH. —next two or three years maybe?

Dr. KEARNS. The pace of innovation is accelerating.

Chairman SMITH. Yes.

Dr. KEARNS. You know, I think certainly within the next five years, we'll see a very dramatic change in the field of energy storage both in terms of grid and transportation technology.

Chairman SMITH. Okay. Good. Thank you. Final question to all of you all, and that is what steps are the national labs taking to reduce the cost of nuclear power? We all know that nuclear is clean, it's a little expensive. If we're going to encourage the use of it, we need to reduce the cost. So what steps are you taking and how optimistic are you that we will be able to reduce those costs? And I guess we'll just work our way through Dr. Peters and then Dr. Seestrom.

Dr. PETERS. Thank you, Mr. Chairman. First on the existing fleet, as I summarized the DOE's Light Water Reactor Sustainability Program that INL and Oak Ridge and Argonne all have a role in is focused on trying to not only sustain the existing fleet but also drive down operating costs for the existing fleet, so that's one. In advance reactors I think going to modular construction, modular manufacturing and construction and—but the advance reactors I think are the opportunity to really—to do research and development to try to drive down system costs because the economics of nuclear, it's probably the thing that has to be addressed.

Chairman SMITH. Great. And, Dr. Seestrom?

Dr. SEESTROM. No comment on this one.

Chairman SMITH. Okay. Dr. Maxon, no comment?

Dr. MAXON. No comment here. Okay. Dr. Kao?

Dr. KAO. No comment.

Chairman SMITH. Oh, my gosh. This is—you don't have—I mean, there's an old adage that scientists should be able to talk one minute on any subject, so—but we won't push you.

And Dr. Kearns?

Dr. KEARNS. I will offer a couple of thoughts, and one is, as Mark mentioned, Dr. Peters mentioned, we are active—very active in terms of collaboration with both Idaho and Oak Ridge in advanced nuclear energy, and one of the current efforts underway that I think is really a great model in terms of working with industry is GAIN, the Gateway for Acceleration of Innovation in Nuclear Technologies, and so we're really pleased to be a part of that. And Mark probably can speak more eloquently than I to the impact, but it's really a wonderful opportunity if you will for companies interested in nuclear technology, developing advanced reactor technologies to really come and engage with the Department and its laboratories, use our facilities, and partner shoulder-to-shoulder with our researchers, and so it's really a great opportunity in that way.

Let me pass it back to Mark in case he wants to say anything more specifically on GAIN.

Chairman SMITH. Okay.

Dr. PETERS. Is that okay, Mr. Chairman, if I just—could I just elaborate a little bit?

Chairman SMITH. Sure.

Dr. PETERS. So, yes, thanks, Paul, very much.

And I would tie it back to this Committee's had a lot of discussions about R&D testbeds and the ability of government sites to ultimately demonstrate technologies. That's what GAIN is. That's what the Gateway for Accelerated Innovation in Nuclear is. So what you all are talking about in your deliberations is actually starting to happen out there.

Chairman SMITH. Good. Okay. Very good news. Thank you all.

And the Ranking Member, Ms. Johnson, is recognized for her questions.

Ms. JOHNSON. Thank you very much. To all witnesses, if the President's proposed budget for fiscal year 2019 was enacted, DOE's renewable energy R&D portfolio would see a 60 percent reduction. The sustainable transportation budget would get a 70 percent cut, and energy efficiency activities would be cut by 80 percent. It would cut critical research on the electric grid by over 50 percent and would cut nuclear energy and fossil R&D by 25 percent each. And it would eliminate ARPA–E and the Loan Programs Office. I'd like each of you to please describe the impact of these proposed cuts on the research capabilities and personnel of each of these labs, and then what are the consequences of drastically reducing U.S. R&D for U.S. competitiveness in a globalized economy?

Dr. PETERS. Thank you, Ranking Member Johnson, for the question. So I'll speak at it from the perspective of the Applied Energy Programs because that's really what effect I know. So we get funding from the Office of Nuclear Energy, Energy Efficiency, Renewable Energy, and the Office of Electricity, all three. If we were to— if those cuts as propose we're to be realized, we as a laboratory would have effects and capabilities in applied materials science and engineering, in chemical engineering and nuclear chemistry and nuclear engineering, as well as in user facilities, so there would be—we wouldn't lose capability but we would have impacts on those capabilities.

Now, I don't have to remind you that this is a process, and so— but the numbers, if we took it at face value, would be order of ten percent of the INL workforce. But watching the process play out, I'm not anticipating significant reductions once Congress weighs in, and we will respond to Congress' appropriations.

Dr. SEESTROM. Thank you, Congresswoman. Sandia has a substantial portfolio in Applied Energy Programs, roughly $140 million. Without seeing the details of the cuts, it's hard to say the exact impacts to our programs, though it's surely true that many deliverables would be slowed down. Because of our broader national security portfolio, we have some ability to move staff between our energy programs and other programs in the lab, so we don't anticipate that we'd have any reduction in force but would certainly lose traction on important research.

Dr. MAXON. At Berkeley Lab I guess I would say the same situation is true, that without the details it's really hard to know how these cuts would manifest. That said, we could predict something on the order of 100 FTEs lost in particular areas of the lab. I mentioned the Agile BioFoundry as one particular collaboration facility that's funded by EERE. There would be serious impacts to that, and that affects not only academic users but also industry as well.

And finally, I would mention the FLEX Lab, which is a fully instrumented collaboration facility that's used by a large number of academic and industry users. There would be some serious effects there as well.

Dr. KAO. For SLAC, Congresswoman, since we have a relatively small program in EERE the impact would really be small.

Dr. KEARNS. And at Argonne about ten percent of our funding comes from the Applied Energy Programs, and much like other— my other colleagues here, it's a little hard to know really what the impacts would be without the specifics of the program in terms of where the cuts would be made.

I will say Argonne works across the spectrum, as I talked about, a continuum from discovery science to use-inspired to translational science and certainly funding for the Applied Energy Program is really—allows us to complete that continuum if you will and really work closely with industry, so we're strong supporters of the applied energy portfolio in the Department and would encourage the Committee and Congress in general to continue its hard work on behalf of those programs.

Ms. JOHNSON. Could you comment on the elimination of ARPA–E? Either one?

Dr. PETERS. I mean, INL doesn't currently have active ARPA–E projects, so I can't speak at it from the lab's perspective. I will say that from the broader perspective in my opinion, I've watched ARPA–E and I've seen a lot of success come out of ARPA–E.

Dr. KEARNS. I would also add, if that's okay, to that comment by indicating that ARPA–E—you know, one of the requirements for funding there is that we bring an industry partner, an industry partner brings in the laboratory if you will to apply for the funding there, and so it's a great model of working with industry I believe.

Ms. JOHNSON. Thank you very much. My time is expired.

Chairman SMITH. Thank you, Ms. Johnson.

The gentleman from Oklahoma, Mr. Lucas, is recognized for his questions.

Mr. LUCAS. Thank you, Mr. Chairman. And I thought that one-minute rule on any subject applied to Members doing town meetings. Weak attempt at humor.

Dr. Maxon, in your prepared testimony you discuss Berkeley Lab's extensive work in fundamental biological sciences, as well as technology to create better biofuels, more resilient crops, and bio-based chemicals. And in all fairness, I have the privilege, in addition to serving on this great Committee, of serving on the Ag Committee. And I'm a farmer by trade, so let's expand for a little bit. Could you provide more information on how researchers at Berkeley are improving these processes?

Dr. MAXON. Thank you for that question. I'll take a shot at that. From an agricultural perspective, I mentioned the microbiome science, the uncharted territories of the billions of organisms that are in every gram of soil. One could imagine that, with a deeper understanding of how these microbials communicate with each other and influence the environments around them, it's not too far-fetched to suppose that there would be opportunities to improve, through the soil itself, abilities to provide fewer inputs to the soil, that plants would be able to—crops would be able to get along with less water, less fertilizer because the microorganisms themselves could be enhanced to deliver those nutrients like nitrogen and phosphorus directly to the crops.

Mr. LUCAS. Well, along that line, your testimony mentions the Joint BioEnergy Institute, JBEI, and looks at improving those bioproducts at the molecular level. Give us some examples of how JBEI can accomplish this but only in a national lab-competent environment.

Dr. MAXON. Yes, thank you. So you can imagine that one such bioproduct could be an enhanced biofuel crop, one that's got more sugars to convert to fuels or chemicals that are desirable, and as well as the chemicals themselves, one can imagine that new types of plastics with higher desirable properties and thermal behaviors, as well as, for example, enzymes. Laundry detergent enzymes are ones that we use every day. That particular market, for example, is on the order of $6.2 billion, so being able to do end-to-end scientific discovery from discovery to use-inspired and then hand off to companies is something that the national labs and JBEI in particular is very good at.

Mr. LUCAS. Taking this one step further, I'm also fascinated by the nexus between high-performance computing research at Berkeley, particularly how Berkeley is using the supercomputers to analyze massive amounts—I think that's the appropriate phrase, massive amounts of biological data to learn more about everything from microbes to biofuel. What are the limitations to today's computing systems when you're trying to solve these complex biological challenges?

Dr. MAXON. We as biologists are, I would say, a bit behind some of the other fields such as physics in big data understanding and approaches. So I think one of the limitations is trying to impart if you will our bioinformatics approaches that we use today to analyze genomes and predict protein clusters and those important aspects to a high-performance setting. We don't have the right kinds of algorithms, and biologists and computing scientists don't even speak the same language. So I think one is technologies themselves. I think the other is bringing the disciplines together to work more productively like physicists and computer scientists do.

Mr. LUCAS. Expand for just a moment on the technology side of that equation, the physical part where we—where you need to be going.

Dr. MAXON. Yes, so this is not my area of expertise, but when you think about using computers that have multiple cores, that means the algorithms run very differently than the computers that don't use multiple cores, and so the things that we are set up to do today—let's say analyzing a genome—can take on the order of, I don't know, 40 days. You—transporting that with new hardware and new software to a high-performance platform, you can do the same type of analysis in about an hour.

Mr. LUCAS. Thank you, Doctor. And I would hope my dear old freshman agronomy professor from Oklahoma State, Mr. Chairman, would be proud that I focused on the important issues. Thank you. I yield back.

Chairman SMITH. Thank you, Mr. Lucas.

The gentlewoman from Oregon, Ms. Bonamici, is recognized for questions.

Ms. BONAMICI. Thank you very much, Chairman Smith and Ranking Member Johnson and all the witnesses, and happy Pi

Day. Before my questions, I want to recognize Muhammad and Raley, who are high school students from Oregon who are here today. They are finalists in the Regeneron Science Talent Search, so please welcome them and keep your eye on them. They are our future leaders.

So to the witnesses, President Trump has released his budget for 2019, and I'm very concerned with many of the proposals. Our nation is dealing with a growing global demand for energy, for over—we have an overreliance on fossil fuels and harmful emissions that are contributing to climate change. We need to be investing more, not less in research and development programs, especially to keep our air and water clean.

Oregon has been a leader in renewable energy projects, and I'm interested in hearing from our witnesses about how to advance these efforts nationwide.

Dr. Kearns, I'm glad you're here today with your background at the Pacific Northwest National Laboratory.

The office in Portland has led efforts to improve energy efficiency in residential and commercial buildings; to strengthen renewables such as wind, water, solar; and to expand storage systems for electric vehicles. The innovative work of labs like PNNL benefits from consistent federal investment, but unfortunately, Congress has been governing crisis to crisis with a series of short-term continuing resolutions. That lack of consistency affects research, but it also affects infrastructure. For example, facility upgrades or new construction cannot begin. The United States is competing, as we know, against other countries that have dedicated, significant, long-term funding to science and research.

So could each of you discuss your perspective on how the lack of stability and funding has affected projects at your labs and how that affects our global competitiveness? And I do want to reserve a little bit of time for another question. Dr. Kearns, would you like to start?

Dr. KEARNS. Certainly. As Dr. Peters commented in his introductory remarks, stability and funding is really critically essential for, if you will, working across the continuum of research that I spoke to in terms of discovery science, use-inspired science, and translational science, and so it's important that there be a stability of funding so that one can do the needed planning and actually conduct the research and have it proceed in a way that allows accomplishments or expected expectations to be realized, so it's very critical in that regard.

Ms. BONAMICI. Thank you. Anybody else want to add on to the—how the lack of consistency in funding has affected your work?

Dr. KAO. Maybe I can add something? So a lot of us actually are involved in construction of major projects. These funding profiles, if you have a continuing resolution, if you're on the upswing curve, you're stuck with a lower level from the year before, that tends to extend the total length of the project and increase the cost.

Ms. BONAMICI. Does anybody want to comment on how that lack of consistency is affecting our competitiveness globally? Dr. Seestrom, I know you—you look like you're ready to speak.

Dr. SEESTROM. So I would make two comments, one, that I think it's quite scary globally. You know, several of our staff recently re-turned from a solar energy conference in China, and their work is quite impressive. They have large efforts in renewable energy. I think that other countries aren't slowing down. And, you know, our scientists can work on many things, and when we have funding shortages, they will walk with their feet to the things that are funded.

I'll mention from our NNSA mission, not energy specifically but, you know, funding delays have impacted our major—one of our major starting LEPs, the W80–4. It's hard to start any new project when you have continuing resolutions.

Ms. BONAMICI. Right. And I'm going to ask Dr. Kearns, Dr. Maxon, what role does energy storage play in promoting clean energy? For example, at the National Energy Technology Laboratory in Albany, Oregon, where they're currently developing sensors and controls that enhance the efficiency of power plants and the electric grid, their efforts should be a model. Energy storage has implications of course for national security and competitiveness as we move toward lower-emission and zero-emission energy sources. So what about energy storage and promoting clean energy, reducing emissions, and increasing efficiency of the grid? Is our nation staying competitive in energy storage technologies? Dr. Maxon?

Dr. MAXON. Energy storage technology is not my area of expertise, but I do know at Berkeley Lab there is an industry consortium that's spun out of our focus on energy storage, and this industry consortium called CalCharge is enabling the stakeholders to work together and collaborate in whole new ways to accelerate more technology development.

I would say, though, that it's very likely that with a more consistent funding profile that we'd see more advances more quickly.

Ms. BONAMICI. Thank you. And I see my time is about to expire. Thank you. I yield back. Thank you, Mr. Chairman.

Chairman SMITH. Okay. Thank you, Ms. Bonamici.

The gentleman from California, Mr. Rohrabacher, is recognized.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman, and thank you for your leadership over the years on this and other issues where you have provided us great hearings like this that are expanding our understanding of science and the important role that people like this are playing, so thank you very much.

Mr. Chairman, one of the things that I have been frustrated about with the scientific community—and maybe it shouldn't be frustration with the scientific community; I should—I'm going to ask your opinion on that—is we seem to be still basing our electricity production on things that are either risky or too dirty, you know? Or something like that. Maybe—could you—and I have understood over the years that we actually have the capability of producing, for example, the next generation of nuclear power. In fact, Dr. Peters, you mentioned that research. Where are we right now? And getting away from light-water reactors and into the next generation of reactors that are safer and actually have a lot of potential, could you—where are we at?

Dr. PETERS. So thank you, Congressman. So first on the existing fleet, I wouldn't characterize them as dirty or unsafe. That would be my first comment. They're operating safely and securely, and they will continue to do so for decades. That said, there is an exciting number of new advanced reactor concepts that are emerging.

Mr. ROHRABACHER. Well, I was actually talking about other sources——

Dr. PETERS. I figured. I just thought I'd put that in there.

Mr. ROHRABACHER. Okay.

Dr. PETERS. I won't go with the other part of this. So—but the advanced reactor, there's a lot of companies that are emerging. I know you're familiar with General Atomics. They're not emerging; they've been around for a long time, but they've got some interesting concepts. There are startups that are popping up, and they're working with the labs, so some of those companies are talking about having First Commercial in 2025 to 2030.

Mr. ROHRABACHER. We actually have prototypes working of the next generation of nuclear power?

Dr. PETERS. We—when can we?

Mr. ROHRABACHER. No, do we have any?

Dr. PETERS. We do not.

Mr. ROHRABACHER. And we've spent billions of dollars, billions of dollars of research on this, and yet we don't have even a prototype working. Now, is this lack of progress due to being stymied by scientific obstacles that we can't seem to get past, or is this a result of regulation and bureaucracy?

Dr. PETERS. It's actually the—I'm not a company that's trying to innovate and develop a concept, but I would tell you they would probably tell you it's capital. Finding private capital to take it to the next step is probably their biggest hurdle.

Mr. ROHRABACHER. Capital. But we have—in the meantime, we've spent billions of dollars supposedly on research.

Dr. PETERS. And we have, and we've done that research. And so they're prepared to take it to commercial, but they have to seek significant private capital to take it to the next step. There's a partnership with the Federal Government, but you can't expect the Federal Government to carry the entire freight for commercializing their unit, so they're going to have to find additional private capital.

Mr. ROHRABACHER. Well, I would hope that that would be one of our major goals is to finally have—with all the great research that has been done on getting us away from light-water reactors, which I believe are dangerous and leave us with basically pollution in the sense that we have to store the nuclear rods forever. We should get away from that and we should be going onto this next generation. And so thank you very much. I would hope that that message gets through.

One—and on the end there, Mr. Kearns, you were talking about the batteries. In the Chairman's hometown in Austin Texas, Dr. Goodenough has been—has supposedly had a breakthrough and—a major breakthrough on this. Would you say that this is accurate? Is it a breakthrough or is it being hyped?

Dr. KEARNS. I'm not—unfortunately, I'm not that familiar with the breakthrough that's been described. I've heard some things in the press, and it sounds impressive certainly, and it certainly would—I pay a great deal of respect to Dr. Goodenough. I think it certainly warrants some additional follow-up.

Mr. ROHRABACHER. And, Mr. Kao, you were shaking your head yes about—you seem to—do you know about that project?

Dr. KAO. Yes, but like all science, you need more people to go into it and repeat and to make sure it's all correct.

Mr. ROHRABACHER. But would you say that on your preliminary look on this——

Dr. KAO. The concept, yes.

Mr. ROHRABACHER. So you—okay. We had another panel here of course talking about that, about batteries and most everybody gave it a good thumbs-up. What we are interested in making sure is that the money that we are spending on research actually is not done for the sake of research but instead is done to make sure we're doing things that improve the life of the people on this planet. And that's why I'm sort of trying to focus on the next generation of nuclear power and things such as that. And we're behind you, and we like—we want things to be done more efficiently, but we also want to make sure the results are actually put into practice in a way that will improve life. So thank you very much.

Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Rohrabacher.

The gentleman from California, Mr. McNerney, is recognized for his questions.

Mr. MCNERNEY. Well, I thank the Chairman, and I think I cut in front of the gentleman from New York——

Mr. TONKO. But he's not yelling.

Mr. MCNERNEY. Okay. But he's going to let me do this. I'd ask, could anyone on the panel enlighten me on the distinction between early-stage and late-stage research or is that sort of a fantasy to think that there's such a distinction? Anyone on the panel want to take that?

Dr. SEESTROM. So there are different ways one talks about research. The DOD uses technical readiness levels. It's a continuum, as I think Dr. Maxon said. We like to think about in terms of basic research. As a national security lab, we do a bit of that, but our focus is on use-inspired going to really applied research. I think the key distinction is how you can cross that valley of death between when you know the science and the technology, but the receiving end in industry is not yet sure enough to invest their money to see they have a product.

Mr. MCNERNEY. So I've heard a lot about the valley of death, and in fact I was in industry for a while, so I know personally about it. Wouldn't it be better to think of it on a case-by-case basis than saying, well there's early-stage and late-stage research and we have to defund late-stage research?

Dr. SEESTROM. I do not see that it's useful to talk about defunding any research based on that distinction.

Mr. MCNERNEY. Thank you.

Dr. PETERS. May I—sir, may I—

Mr. MCNERNEY. Sure.

Dr. PETERS. —real quick? To your last point I would draw out nuclear energy as—it is case-by-case in some sense. The Federal Government role for getting to commercial nuclear energy technologies is different perhaps than it might be for another energy technology, and as you know, there's been a long-standing federal partnership with the private sector but, you know, doing the science, doing the applied science, but actually going out to first-of-a-kind demonstrations for some of these advanced technologies is probably—there's probably an important government role in there, so that's important to remember.

Mr. MCNERNEY. Well, thank you. And there's some significant cuts we're seeing in the Administration's budget. You've got to think that the valley of death is going to get wider with that sort of a cut. Is that a good assessment? I see headshaking but that's about it. Nobody wants to speak up.

So, given the budget cuts, does anyone want to talk about what their—what specific—a specific program that they like that's going to suffer from this? I mean, fusion, for example, we're going to suffer because we need to be invested in ITER. Even though it's taking place overseas, America gets a lot of bang for that buck. Are there any other programs that anyone wants to talk about that are going to see harmful cuts that are going to harm our national interests? Yes, Ms. Maxon?

Dr. MAXON. I'd like to mention that for the Department of Energy's Biological and Environmental Research program, there are some serious proposed cuts to earth and environmental science studies, and from my perspective, if you think about understanding the subsurface, this is important because that's where carbon, nitrogen, and phosphorus, all these building blocks of life are. And that particular program that I just mentioned studies the watershed system and how the water—how do we—what about drought resilience and how do the nutrients and contaminants move underground? I think that's a very serious—that would be a very serious loss, our ability to predict resilience in local communities to extreme weather.

Mr. MCNERNEY. Well, since I'm from California I sarcastically don't care about drought resilience.

Yes, Dr. Kearns?

Dr. KEARNS. Yes, I just would like to build on that a little bit in terms of biological and environmental research. One of the key things that's underway there in the earth and environmental systems sciences program is really the evolution if you will or further development if you will of our system's computer models to actually run on our new exascale systems, and so it's a critical component that needs—requires continued investment, continued support in terms of funding.

And it does really—you know, development of enhanced models here really improves our ability to understand the global hydrologic cycle. It gives us deeper insights, as has been mentioned, into future droughts, floods, wildfires, and other concerns I know in California in hurricanes and agricultural sustainability as well, so many topics that have been touched on here today, so critically important that we continue to invest so that we can further our understanding.

Mr. MCNERNEY. Are labs an important element in bringing together scientific collaboration? Is that going to be harmed by these kind of cuts? Yes, Ms. Maxon—Dr. Maxon.

Dr. MAXON. It's my opinion that the labs are really an integrator of communities of researchers. You've heard about the scientific user facilities. That's an obvious example. But there are other programs like, as mentioned before, the Joint BioEnergy Institute, for example, that brings together universities and national labs and companies to work together on problems, so I do think that this is seriously at risk, the integrator function and collaborations.

Mr. MCNERNEY. Thank you. Mr. Chairman, I'll yield back.

Chairman SMITH. Thank you, Mr. McNerney.

And the gentleman from Texas, Mr. Weber, the Chairman of the Energy Subcommittee, is recognized.

Mr. WEBER. Thank you, Mr. Chairman.

Dr. Peters, I'm going to move over here a little to my left. It'll be one of the rare times I do. This Committee has taken a leading role in advocating for advanced nuclear energy research. Specifically, my bipartisan nuclear energy research legislation has passed the House on multiple occasions. This bill would authorize the construction of a research reactor, a versatile neutron source. I wish the gentleman from California was here but—Mr. Rohrabacher could hear this questioning—which you mentioned in your testimony the nuclear versatile neutron source. And it'll open up for national labs for the development of prototypes for advanced reactors. That's the aim.

So, Dr. Peters, why is it important in your opinion for the Department of Energy to invest in a research reactor?

Dr. PETERS. So we—thank you. Thank you, Mr. Chairman. Thank you for all the support of what we do.

So just quickly, we do operate test reactors already. INL operates the advanced test reactor and the transient test reactor, two large reactors. The high flux isotope reactor is operated at Oak Ridge. So they operate at a certain—not to get too much into the physics, but they produce thermal neutrons as opposed to fast neutrons, which your new proposed reactor would do.

So we have that capability, but if a company or a university professor or lab person wants to do research on materials that would be apropos to a reactor that's operating in a fast neutron spectrum, they have to go to a place like Russia or a place like China to get those fast neutrons. So, right now, the United States does not have that capability.

Mr. WEBER. Right, and that's unacceptable. I think Dr. Maxon said earlier about companies are reluctant to invest until they see the dependability of something coming on.

So if the United States does fall behind—you mentioned Russia and China—that has international implications in nuclear research?

Dr. PETERS. It does, and it also has national security implications more broadly. If we're not—if we don't have a strong civil nuclear sector, we don't have a seat at the table internationally.

Mr. WEBER. Right. Well, I want to go back to Chairman Smith's question about the battery for Dr. Kearns. Can you give us the time frame on when that five times more powerful battery—when can we expect this versatile neutron reactor?

Dr. PETERS. Oh, the versatile fast neutron source could be in place, pending appropriations, in 10 years.

Mr. WEBER. Ten years, okay.

Dr. PETERS. Yes. Yes.

Chairman SMITH. Well, we get a better answer from Dr. Kearns, who said within five years.

Dr. PETERS. Yes, right.

Mr. WEBER. Okay. All right. So can we——

Dr. PETERS. Well, it's nuclear versus battery, sir, so——

Mr. WEBER. So maybe we need to have some bidding going on here. If this legislation is signed into law, what role do you expect INL to play in designing and building this test reactor?

Dr. PETERS. We already have a team formed with actually Argonne and Oak Ridge. My hope is is that it would be built at the INL. I've got a place picked out that's ready to go, but we've got a team for them, so as appropriations come on, we're ready to run.

Mr. WEBER. Okay. And, Dr. Kearns, how about the Argonne National Lab? We seem like we have some collaboration going on here.

Dr. KEARNS. Oh, yes, absolutely. And certainly Chairman Smith paid a very nice tribute if you will to Enrico Fermi, really the founding further of Argonne, in his opening comments. And Argonne's maintained if you will a deep expertise in nuclear technology from day one, and we are very actively partnered with Idaho and Oak Ridge really in terms of development in the new test reactor. We like to think that there's a little bit of Argonne in every nuclear power plant that's been built, and certainly we continue to really want to participate in a very active way in supporting the development of the test reactor——

Mr. WEBER. So is it your testimony here today that you'll put pressure on him to get it down to five years?

A question for all of you in my last minute. Last Congress, the House passed the *America COMPETES Reauthorization Act*, which provided National Laboratory Directors with the flexibility—the ability to authorize cooperative research agreements in priority research valued at up to $1 million. Good thing, bad thing? Dr. Seestrom, I'll go to you.

Dr. SEESTROM. I think it's a very good thing.

Mr. WEBER. Okay.

Dr. SEESTROM. These kind of CRADAs advance our interests substantially. I'll just mention one example. Sandia has worked with Goodyear through CRADAs for over 25 years. We brought our advanced modeling and simulation capabilities to their business of designing tires. You might not think that nuclear weapons and tires have a lot in common, but the kind of material interactions that we deal with in both areas are significant.

Mr. WEBER. Okay.

Dr. SEESTROM. They're able to improve their time to market, and we're able to improve the codes that we do for the nuclear weapons.

Mr. WEBER. Perfect. Let me move to Dr. Maxon. Good thing, bad thing?

Dr. MAXON. Definitely a good thing. I—well said. I can't add much more. We have plenty of examples, too.

Mr. WEBER. Okay. Dr. Kao?

Dr. KAO. Good thing as well.

Mr. WEBER. Dr. Kearns?

Dr. KEARNS. Yes, a very good thing, very——

Mr. WEBER. Okay. Dr. Peters?

Dr. PETERS. Good thing, and we need more things like it.

Mr. WEBER. Okay. And we're working on that.

Mr. Chairman, I've got three seconds I yield back to you.

Chairman SMITH. Thank you, Mr. Weber.

The gentleman from New York who should have been recognize earlier, Mr. Tonko, is recognized now.

Mr. TONKO. It's all right, Mr. Chair. Thank you. And welcome and thank you to our members of the panel.

Our national labs are I think a best-kept secret at times and a tremendous empowering resource for this nation. And so including our national lab at Brookhaven in my home State of New York, you're leading us into the future using fundamental science that will change our understanding of the world around us and our universe.

I'd like to continue along the questioning that Congressmember Bonamici indicated on energy storage. How can energy storage be combined with utility-scale solar and wind farms to help reach our clean energy and environmental goals in the longer term? Dr. Kearns?

Dr. KEARNS. Yes. I believe energy storage is really—would be a great enhancement if you will to utility-scale solar and wind as well. As you know, those sources tend to be intermittent depending upon the climate and the weather if you will, and so it's important to have a way to store energy produced in that way so that we can discharge it when needed and really have the additional reserve if you will. And it also provides for a better balance across the—if you will the grid, really allowing electricity to be deployed when and where needed.

Mr. TONKO. Thank you. And, Dr. Peters, how could storage better enable a zero-emission hybrid energy system that includes both intermittent renewables and advanced nuclear power sources?

Dr. PETERS. It's—modular nuclear reactors and storage together are probably the way you change the game in my opinion. The future energy system is probably a lot of renewables and a lot of nuclear, but you have to have storage. But the way that modular reactors work, you can run some modules full out and others can be modulated to complement the storage. So we're doing a lot of work actually—INL along with National Renewable Energy Laboratory in particular—on so-called hybrid energy systems, as you commented on, Congressman. So there's a lot of research going on already, and we're starting to engage in industry, both end-users, utilities, as well as energy providers to figure that out, but it's a quite exciting area of applied research.

Mr. TONKO. Thank you. And, Dr. Maxon, the Office of Science was flat-funded in the budget request, but there were harmful cuts to important research within the Office of Science. The Biological and Environmental Research program would be cut by 18 percent. Many would probably not be surprised to learn that BER is the largest sponsor of climate change-related research at DOE. And you talked about that impact on the earth and environmental systems sciences area. For those in the Administration or any that support these sort of cuts that think climate change is unsettled science, wouldn't it make sense then to further invest in the research to give us a clearer answer on the state of our climate?

Dr. MAXON. Well, it's my opinion that understanding where critical elements that drive the Earth's biogeochemical cycles—carbon, phosphorus, nitrogen, sulfur. Understanding those things in great detail is really important not only for climate science but also for the biological sciences, too, so I do see a significant benefit.

Mr. TONKO. Yes. And I really do believe a lot of our decision-making should be formulated by science and research. Our biological systems science has fared much better in the budget proposal, including increases to genomic science and flat-funding for the Joint Genome Institute. What are additional areas of opportunity that we should consider exploring for biological systems sciences?

Dr. MAXON. I think that's a great question. One of the things that I think remains largely untapped is the bringing together of biological sciences and material sciences. I mentioned the Agile BioFoundry that exists to reduce the cost and increase the speed of generating biological products. We don't yet know how to make a lot of things that, for example, don't exist yet. As I mentioned potentially plastics that have profiles that are improved over others. How about things that don't exist yet? Shatterproof Bioglass, bringing together materials science and biological sciences, I think that's a great opportunity.

Mr. TONKO. Wonderful. And in a few—half-a-minute we have left, what is the status of microbiome research at DOE?

Dr. MAXON. DOE is a leader in microbiome research, along with the USDA, co-chaired the Microbiome Interagency Working Group that put together a strategic plan that I'm hoping will become public someday so we can see what the great opportunities are for the nation's microbiome science.

Mr. TONKO. Wonderful. And thank you again for all the leadership you provide with our labs and for the resource that our labs happens to be.

With that, Mr. Chair, I yield back.

Mr. WEBER. [Presiding.] I thank the gentleman.

Mr. Hultgren, you're up next.

Mr. HULTGREN. Thank you, Chairman. Thank you all so much for being here.

I think all my colleagues on this Committee and hopefully throughout Congress know my passion for our laboratories and just incredible work that you all do and just feel like it is such a vital part of who we are as a nation is our laboratories. And so I just want to congratulate you and thank you and celebrate but also know that we've got work ahead of us.

Specifically, for me having the privilege of representing Fermilab and having Argonne just a few miles outside of my district, I get a chance to go quite often and see the truly groundbreaking work that happens and the breadth of research that is happening just between those two labs and then you put on top of it all of the other labs, it is wonderful and exciting, but I see unlimited potential if we continue to do the support we need to do and give you all the ability to do the long-term planning and present the visions of what could happen if you have that confidence of knowing that we are supporting you here in Congress. Really, the sky is the limit, so excited about that and just want to thank you for—all for being here.

I had the great opportunity to also visit Sandia last May and Berkeley last September, and each lab was truly uniquely situated and breathtaking.

Dr. Peters, since you and I met at Argonne, you've always been an incredibly valuable resource on nuclear security issues, as well as a strong champion for the steps the Nation need to take to realize the next generation of advanced nuclear power. I know Idaho National Lab is proud to have you, but I still kind of like the old name Argonne West if there's any way that you might be able to continue to work on that.

One thing—and I'd ask my question for all of you if you can have maybe a quick thought or statement on this. One thing that I think is important about the work that you're doing is the ability that you have to inspire the next generation of young scientists. Here in the House we do a Congressional app competition, and a few years back I brought my winner through Argonne's computing facilities to show him what he could accomplish if he continued to learn how to code and improve his STEM skills.

Fermi also brings in literally thousands and thousands of students every year for STEM activities, as well as teachers, who they train, how to make accelerators with high school students throughout the country.

I wondered if each of you could talk a little bit about the STEM activities that your lab is involved in and how much of this is voluntary for staff. At Fermilab I know we have Science Saturdays, which is basically volunteer driven. Also, what authority from DOE might make it easier to work with students in classrooms across the country to help to get mentors and experts where they're needed most? Should DOE look at this as workforce development?

And maybe we'll just go down the line, start with Dr. Peters, and if you have a thought of what your lab is doing, specifically focus on what we can do to help increase that.

Dr. PETERS. Yes, Congressman, great to see you again, sir.

Mr. HULTGREN. Good to see you.

Dr. PETERS. Argonne is still here.

Mr. HULTGREN. Good.

Dr. PETERS. But INL is a great place to be.

Mr. HULTGREN. It is.

Dr. PETERS. So we're doing a wide variety of things. Let me take—it is about workforce development for—to your final point. We're doing a lot of some direct funding from the government, quite a bit of our own indirect investment going back into it, but also a lot of volunteer.

Some examples, we're doing a lot particularly focused on STEM, no surprise, but trying to bring kids to the lab, much like you see at FERMI and what you see at Argonne. It's the—this isn't rocket science, right? You get them in there and get them excited.

We're doing a lot of teacher professional development as well, bringing teachers in to show them what we do so that they can get the kids excited, but I love it when the kids actually come to the lab. We're building internship programs much like I was used to at Argonne at INL. Just last week, we had My Amazing Future, which is basically introduce-a-girl-to-engineering day, which that's the one that I almost like the most.

Mr. HULTGREN. Yes.

Dr. PETERS. A bunch of eighth-grade girls come in and we—they interact with our scientists. So we're doing a lot.

In the State of Idaho, I would also put in a plug for the State of Idaho. The State of Idaho is doing a lot of investment in education, and we're a partner with them on that.

Mr. HULTGREN. Good. Let me keep going down the line. Thanks, Dr. Peters.

Dr. SEESTROM. Sandia has a modest number of outreach activities. One I'll mention is at our Advanced Materials Laboratory, which is joint with the University of New Mexico where we bring in a set of elementary school students to see the cool things you can do with materials. Mostly, we're funding that out of indirect and volunteer labor.

We're keen on internship. You know, as I travel around Sandia and see the young engineers and scientists, many of them came to Sandia because they were interns. And we are not so well known as Fermilab and Argonne, and so getting these young people in the door is critical. The last thing is we recently established as a new management team the Jill Hruby Scholarship to honor our previous Laboratory Director Jill Hruby as the first woman Director of a national security lab, and we're about to announce our first two winners of that prize to bring two outstanding young women scientists into the lab.

Mr. HULTGREN. Great idea. My time is expired. If I could—if the Chairman would give me leeway just to quickly—the other three, if you could just mention a thing or two. Thank you.

Dr. MAXON. Yes, thank you. The Joint BioEnergy Institute, which you visited last fall——

Mr. HULTGREN. Yes, it was great. It was awesome.

Dr. MAXON. —has a program focused on undergraduate—oh, sorry, high school students that are underrepresented minorities, who then go through a summer internship and research opportunity that has, over the last ten years, generated over a 95 percent college acceptance rate on those students.

Mr. HULTGREN. Fantastic. Dr. Kao?

Dr. KAO. So for SLAC, we try to leverage the funding from the Department. Recently, we, actually working with Moore Foundation, to encourage girls in middle and high school to come to the laboratory because I think we need to do more to build the pipeline for a more diversified workforce for us.

Mr. HULTGREN. I agree. Thanks. Dr. Kearns?

Dr. KEARNS. Yes, Argonne has a very active education program, great outreach program. One thing that's coming up that I'll mention is activities supported by the Department of Energy Office of Electricity called the Cyber Defense Competition——

Mr. HULTGREN. Great.

Dr. KEARNS. —where we actually bring students into the laboratory. We set up a green team, red team, and a yellow team basically, including representatives from industry and of course it's a bit of a hackathon if you will——

Mr. HULTGREN. Yes.

Dr. KEARNS. —and students compete against each other at various schools. We've got 210 students participating this year. Pacific

Northwest National Laboratory and Oak Ridge National Laboratory have also joined the activity, and so we're pretty excited about that. It happens here April 2 at Argonne so if you're in the neighborhood, please.

Mr. HULTGREN. I'll do my best. That sounds great. Thanks, Chairman. Thank you all so much and yield back.

Mr. WEBER. The gentleman yields back.

We will yield to Mr. Foster of Illinois if he brought a pie for Pi Day.

Mr. FOSTER. Yes, well, it's in the back room there, but if the staff will bring out the remaining crumbs if they haven't already pounced on it.

Mr. WEBER. The gentleman is recognized.

Mr. FOSTER. Well, I wanted to wish everyone a happy Pi Day. It's a day where we celebrate the rational arts of logic, science, mathematics with an irrational number, a number whose digits continue as long and as randomly as, I don't know, politicians' tweets perhaps. But I want to thank you all for coming here——

Mr. WEBER. The gentleman's time is expired.

Mr. FOSTER. I sometimes introduce myself as representing 100 percent of the strategic reserve of physicists in the U.S. Congress. I also represent the 11th District of Illinois, which includes Argonne National Lab, and before coming to Congress, I worked at Fermilab for 23 years. And so I have a special interest among the just incredible scientific facilities that you operate in Argonne's facilities, including the Advanced Photon Source.

On a recent tour of the national labs with Secretary Perry, we visited both Fermilab and Argonne, and I spent the day with him. I was really impressed by his enthusiasm for the crucial science and the research conducted at the labs.

You know, you live in a situation where you have political oversight at the very top levels. In previous Administrations we saw a very strong scientific component at the top levels of the Administration that doesn't seem to be as present in the current Administration. And when we've had, you know, the political level of appointees and below, you know, before this Committee, they have acknowledged that and said how much they depend on the scientific expertise at the labs.

And so your role there is more crucial than ever, and I want to thank you for toughing it out. And we're doing our best to protect you from the proposed budget cuts that would make your life miserable if they came through. Among other things, they would halt the—Argonne's Advanced Photon Source upgrade, which would allow Argonne to rejoin Dr. Kao's lab at the very forefront of leading light sources in the world and the incredible things that you can do with them.

I have actually one specific question on energy storage where I'm working now on a bipartisan bill with Representative Knight talking about trying to set up demonstration programs for grid-scale energy storage. And when you set up a program with specific goals, it's important you set the goals right. I think it's one of the most destructive things we can do is to ask a group of talented technical people to do something that they know is impossible. An example of that would, say, be going to Mars on a flat budget, which is something we routinely ask NASA to do.

And so there are three specific goals that we're thinking of right now: first, to have an installed energy capital cost of $100 per watt and a minimum of one charge and discharge cycle every day. That's a grid scale thing. And a lifetime of 5,000 cycles of discharge and charge at full output. And, you know, you can respond either now or for the record whether those are sufficiently challenging to get the next generation of people interested in it and sufficiently achievable that you're not just asking people to go to Mars on a flat budget.

And so I'd be interested if you have any immediate reactions to those, if they're in the ballpark, because there is a bipartisan interest in—including by our Committee Chair in making the transition to an energy economy that doesn't dump large amounts of carbon dioxide into the atmosphere, and energy storage is crucial there. Yes, Dr. Kearns.

Dr. KEARNS. Let me respond by—initially and then also some—promise some follow-up in terms of a more formal submission, but those look like they're in the ballpark to me. They look like they're aggressive enough and yet realistic enough in terms of where we're at today and where we'd like to drive.

I guess the one question I might have in terms of follow-up is the time frame as to when you'd like to achieve these goals, any established——

Mr. FOSTER. Yes, these would be actually starting—choosing and starting the projects 3 to five years from now.

Dr. KEARNS. Three to five years, okay. So let me get back to the lab and ask a few folks that have a greater knowledge than I do on this subject to make sure that we're responding appropriately, but I'd say they're in the ballpark.

Mr. FOSTER. Yes, thank you. Any other reactions to that?

Dr. SEESTROM. We'll take it offline and bring you back an answer.

Dr. PETERS. Yes, but I concur. They sound properly aggressive, but I think we need to take it for the record so——

Mr. FOSTER. Yes, it's tough. You can't—you know, President Kennedy said we're going to the moon within a decade——

Dr. PETERS. Right.

Mr. FOSTER. —because there were detailed parameters for a mission to the moon that could be achieved with known technology at the time.

Dr. PETERS. Right.

Mr. FOSTER. And so that is—it's a very different thing. It doesn't mean it's easy, it doesn't mean it's certain, but it's important that we set those right.

And, you know, I really want to take advantage of that bipartisan enthusiasm for—now for transitioning to a low-carbon economy. And I am now zero on my clock, so thank you and yield back.

Mr. WEBER. Okay. The gentleman yields back. Thank you.

Dr. Babin, you're recognized.

Mr. BABIN. Yes, sir. Thank you, Mr. Chairman. I want to thank all of you witnesses for being here today, very interesting, very valuable information.

Dr. Kearns, I have a couple of questions for you if you don't mind. At Argonne, a team of researchers discovered a way to attach oil-attracting molecules to polyurethane foam that—the same foam commonly used in furniture and insulation by priming it with the metal oxide glue.

The new and reusable material called the Oleo Sponge can absorb oil from an entire water column, not just up at the surface. The sponges will be used it to clean up oil spills, as well as diesel and oil buildup in ports and harbors. And what collaborative efforts led to this technological breakthrough, and what about the research environment at Argonne that developed this technology? And what steps will be taken by Argonne to transfer this technology to the fossil fuel industry?

And I'll repeat that if you answer the first one and then don't remember what the second one was.

Dr. KEARNS. Thank you. Thank you.

Mr. BABIN. Okay.

Dr. KEARNS. Yes, the Oleo Sponge is a very exciting development. It's really—the genesis if you will was really funded through the laboratory's directed—Laboratory Director's Research and Development program, the LDRD program mentioned earlier by Dr. Seestrom as really essential if you will to really allow the laboratories to really develop new thoughts and pursue new ideas, and so it's initial funding was provided through the vehicle.

It also built upon some capabilities that the Office of Science Basic Energy Sciences program funded through the Center for Nanoscale Materials really. It's a cross-collaboration between two different divisions at the laboratory, one very basic in terms of its approach at the Center for Nanoscale Materials but one more applied in terms of the Energy Systems Division at the Argonne, so great story in terms of where it began, really building off that initial investment by the Office of Science and further developed with LDRD funding and then really a cross-laboratory collaboration.

In terms of what's occurring as we work to commercialize that technology, an opportunity announcement was made I'd say eight, ten months ago. The response has been tremendous. We have over 140 companies that have reached out and expressed an interest in the technology, and we've been in serious conversation with several since that time. We're down to a handful of folks that we're talking to currently that might take an interest if you will in terms of application of this particular technology and develop it for commercial products.

Mr. BABIN. Great. That's excellent.

And, Dr. Seestrom, did you have anything you wanted to add to that since you we're involved in it? Okay. All right. Thank you.

And also, Dr. Kearns, the Technology Commercialization Fund allocates .9 percent of the funding from the Applied Energy Offices to invest in commercialization of energy technology.

When I look at this program and the decision under the Obama Administration to establish the Office of Technology Transitions, I'm concerned that we're consolidating funding decisions in Washington instead of giving more flexibility to our national labs, which tend to have direct relationships with industry and better understand the technology needs. How can Congress work with you to ensure that we don't centralize our technology transfer programs in Washington, which we're trying to not do?

Dr. KEARNS. Good question. I think there are number of things that could be done. One is the labs do, as you suggest, work directly with industry. A good example of an outreach activity at the Argonne National Laboratory is really we held an industry day focused on energy storage, and we had over 100 companies come to the lab really to learn about our capabilities and express interest if you will in terms of their needs, their desires for further development of their ideas. And, as a result of that, a handful of opportunities that develop into CRADAs, the Cooperative Research and Development Agreements, and other examples of the laboratory working side-by-side with industry in that way.

So that's one great example I think of how to work with industry. What you might do is really encourage—as was discussed earlier, encourage more vehicles like the Cooperative Research and Development Agreement and the Strategic Partnership Project efforts the Department of Energy has underway.

I'd also say the Technology Commercialization Fund you mentioned has been very active. We've been—Argonne has been very active and it's been a very attractive program for our industrial programs in that way as well, so a good history, good record there in terms of accomplishments.

Mr. BABIN. Okay. That's great.

Well, Mr. Chairman, I'll yield back eight seconds. Thank you.

Mr. WEBER. The gentleman yields back, thank you.

And, Mr. Dunn, you're recognized for five minutes and eight seconds.

Mr. DUNN. Thank you very much, Mr. Chairman. I thank the panelists for coming here today to inform us about your labs. I look forward to coming to visit you at the labs and probably a lot more informative visits when you can actually teach me in the place.

I'm a physician. I tend to focus on the healthcare in my questions, and if I could start with Dr. Kearns. Millions of people around the world have been helped with medical isotopes in these diagnosis treatment imaging and other diseases, cancer and whatnot. We're—we lack the capacity in the United States to produce all the needed isotopes, and some of our isotopes are in fact produced in highly enriched uranium reactors, which carries proliferation risks.

Your lab is helping two companies develop new methods to make these isotopes in accelerators rather than reactors. I'd ask you to explain why it's important to the medical community to have these isotopes and to the patients to have these isotopes but also why avoid the highly enriched uranium reactors.

Dr. KEARNS. Yes, the last question first, fairly simple to understand. With the use of highly enriched uranium, the concern is one of proliferation and really safeguarding if you will the materials in a way that doesn't allow them to end up in the hands of those who might wish ill on individuals or nations, and so that's really the key component there.

Certainly, you know, one of the primary examples—and the other laboratories involved should—I think in the isotope program should also comment, but the one program that's been active at the Department—at Argonne has been the Moly-99 program, which is funded by the NNSA, working with a couple of industrial companies if you will to commercialize that technology. It's a great example really again of industry-laboratory partnerships and really driving towards a well-defined outcome if you will.

I think the—why do that—Moly-99 is pretty essential really in terms of, you know, how we conduct medicine today. It's critical for the United States because we don't have any domestic production of Moly-99 currently. We're really dependent upon foreign sources, and of course the reliability of the sources is from time to time of concern. And so—

Mr. DUNN. It's actually interrupted my practice on occasion.

Dr. KEARNS. Oh, has it?

Mr. DUNN. And I'm sure I'm not the only one.

Dr. KEARNS. Yes.

Mr. DUNN. So it's important for us to be able to get to those.

Now, some of the isotopes simply cannot be produced in an accelerator, they need a reactor, and I know in recent years we've pushed to move from HEUs to low-enriched uranium reactors, and I understand that, I'm on board, but the low-enriched uranium reactors generate roughly ten times the radioactive waste as the HEU reactors. And the United States has zero capacity to reprocess radioactive waste at this time. I believe I'm right on that. There's no MOX plants in the United States? Dr. Peters?

Dr. PETERS. There's not the capability to reprocess currently, yes.

Mr. DUNN. Okay. And the MOX plant that's been under construction in South Carolina is slow or off-track?

Dr. PETERS. It's behind schedule, overbudget, and it's dedicated to reprocessing of the 34 metric tons of surplus plutonium—

Mr. DUNN. Okay. So that——

Dr. PETERS. —so, no, it's not going to reprocess HEU.

Mr. DUNN. Okay. Well, that's worth knowing. Thank you. And so I invite all the panelists to bend your considerable talents and resources to solving the problem of reprocessing our domestic radioactive waste, which should not be treated as waste in the first place but as a valuable precursor commodity. And I think we all know that the second generation radioactive waste that comes out of these reprocessed and reused—that you've changed the half-life of those—that radioactive waste in the far end of the cycle to something that's a lot rhythmically less, right? I mean, we move from hundreds of thousands of years, millions of years half-life to hundreds of years half-life, so I would encourage everybody to solve those problems. I know you can do it. I have faith in you.

I'm going to sneak in another question if I can on the ultrafast—this is to Dr. Kao—the ultrafast frame rate x-rays you use to capture molecular movies, fascinating stuff. I've seen some of the work that's available. Can you explain how we use that information on a molecular level and how it might pertain to health care?

Dr. KAO. Okay. So what the ultrafast x-ray does is you can take snapshot of a protein that typically these are targets for drug development, and in particular those on the surface of a membrane, membrane protein, they are very difficult to crystallize into crystals, so they tend to be very small. And so with this ultrafast x-ray, you can take a snapshot of these and you drop them down into the x-ray beam, you hit it, it disappears, but you capture the image. You do a million shots of these. You then reconstruct the three-dimensional atomic structure of that, and then you can use that to guide you to develop drugs.

Mr. DUNN. Thank you very much. Mr. Chairman, I yield back.

Mr. WEBER. The gentleman yields back.

The gentleman from Louisiana is recognized for five minutes.

Mr. HIGGINS. Thank you, Mr. Chairman, and I thank this brilliant assemblage of scientists before us. Your testimony has been personally inspiring to me.

Historically, DOE's research programs have had the greatest impact on resources that are focused on completion of certain goals or missions. Our national debt certainly leads us to righteous funding restrictions at the federal level, and that should lead us to a focus on result- and mission-oriented research. In my opinion, this is particularly true for advanced nuclear power.

New modular technologies hold great promise and should be a priority for the Department. I believe we should establish a clear set of goals for completing a program leading to the demonstration of new nuclear technologies, real technologies, achievable technologies, technologies that can be deployed.

Earlier this week, I introduced legislation H.R. 5260, the *Advanced Nuclear Energy Technologies Act*, which would set a goal of demonstrating four commercially competitive advanced reactor designs over the next decade. Setting mission-driven goals at DOE will help the United States regain its global leadership in nuclear energy security, open new markets for domestic power generation, retake a key strategic advantage from China and Russia, and put thousands of American engineers, manufacturers, and tradesmen to work. Further, a robust American nuclear energy sector is essential to President Trump's vision of American energy dominance.

Dr. Peters, how can we better utilize DOE's nuclear programs to expedite the demonstration and ultimate commercialization of small modular reactors?

Dr. PETERS. Thank you, Congressman. First and foremost, let me say that I support what you're trying to do with your legislation. As you know, there's similar legislation coming out of the Senate to look at four demos roughly ten years from now.

Because—but I'm a big supporter of trying to start to drive the R&D program to cost targets to try to drive down the economics and nuclear systems. I think that's important. So the R&D needs to be done now to help us get us to that aggressive demonstration goal that you articulated.

I would also want to say that, in addition to the versatile fast neutron source, which this Committee is already fully supportive of, being able to go actually build these prototype demonstration units would be really, really important for putting us back in leadership position because other countries are doing this. China is building these—prototyping all of these advanced concepts, so it's very important.

The other part of this is where would you put the demos? A place like INL would be a place you could build these demonstrations. I'd be happy to do that.

Mr. HIGGINS. Thank you for your answer. Do you concur that a demonstration of a working prototype is certainly the link to a public-private partnership?

Dr. PETERS. It is. It is because I mentioned earlier about the private sector needing capital, but it's going to have to be a partnership with the government. But I do believe if we get those out to first-of-a-kind demonstration for some of these advanced concepts, that will then enable them to get into the market and move very quickly and penetrate the market.

Mr. HIGGINS. Thank you, Doctor.

Dr. Kearns, do you have anything to add?

Dr. KEARNS. No, I think I fully support what Mark has responded with. I think we're good.

Mr. HIGGINS. Well, I have an additional question a bit that has been really touched on here today. Please respond as you see fit. What steps do your labs take to protect the classified intellectual and proprietary information and property from access, copying, and theft by foreign nationals? Any member?

Dr. SEESTROM. Of course at Sandia, as a national security lab, we place the highest priority on protecting our classified information,. We have very few foreign nationals mainly accessing only external areas of the lab.

Mr. HIGGINS. You feel comfortable that your lab is sufficiently protected?

Dr. SEESTROM. I do. I would say I am as worried about insider threat as I am about foreign nationals.

Mr. HIGGINS. As we should be. Does anyone else have something to add there? We're very concerned about intellectual property theft.

Dr. PETERS. Yes, maybe a little bit on the industry engagement perhaps. I mean all of us—I'm sure we have extensive controls in place, nondisclosure agreements and whatnot, so when we engage industry, we protect that information. And as you heard here, all of us are looking into increase our industry engagement, so that's very, very important.

But we all have the ability to control the culture of the labs because we're dealing with classified material throughout our history. I think the industry engagement really is treated in a very similar way. We have to protect this information very, very carefully.

Mr. HIGGINS. I thank you all for your answers. My time has expired, Mr. Chairman.

Mr. WEBER. I thank the gentleman.

Mr. Biggs, you are up next.

Mr. BIGGS. Thanks, Mr. Chairman. And I'd like to thank Chairman Smith for inviting you. And this is an august panel, and it's been very informative and very interesting and I've learned a lot. And I just am very impressed at what we've talked about today, and thank you for being here.

Dr. Seestrom, after a tsunami damaged the Fukushima-Daiichi nuclear power plant in 2011, massive amounts of seawater cooled the reactor. During cleanup activities, a molecular sieve created by Sandia National Lab scientists was used to extract radioactive cesium from tens of millions of gallons of seawater on the reactor side. It's my understanding that this technology was developed using Laboratory-Directed Research and Development, LDRD, funding at Sandia. Can you tell us a little more about how the technology was developed and how it made its way to Japan to play such an important role in the cleanup?

Dr. SEESTROM. So thank you very much for that question, Congressman. This is actually quite an informative story. So as you probably know, molecular sieves are crystalline substances, and the size of the pores limit the size of molecules that can go through. So the particular technology that was developed at Sandia in one of our earliest CRADA work with industry, crystalline silico-titanate had specific strength for removing cesium. We had a partnership with a company called UOP actually based I think in Des Plaines, Illinois. We licensed it to them. This was back in the '90s, we won an R&D 100 award based on that.

When Fukushima came along, one of our eminent senior scientists, the chemist Tina Nenoff, who had worked on disposal of waste and cleaning of products at Hanford for a long time, was able to quickly test the CST for its applicability to putting the seawater through it, found that it would work just fine, and UOP managed to work with TEPCO in Japan to put that on the ground there.

Mr. BIGGS. It's fascinating. That's a great story. So you've talked about LDRD funding being a key part of how the labs pursue new research opportunities. What steps can Congress take to facilitate more of this flexible but mission-focused research?

Dr. SEESTROM. Well, continue the good work that Congress has done in setting both an upper threshold and a lower threshold for LDRD. We value every penny of that research. I could, if we had time, give you a list of five different inventions that came out of our LDRD program that transformed our missions, including our work in rad hard micro semiconductors, so just keep the limits there for us.

Mr. BIGGS. And so I want to talk about the budgeting because people talked about the CRs and its detrimental impact on all of you, but I'm new to Congress and we're going to vote on our seventh CR in six months, and I'm kind of embarrassed by that. I hope—there's not enough people in here to join me in my embarrassment. But over the last 20 years we've done more than 100 CRs, an average of five—in excess of five, almost six CRs per year, and I'm—you know, I realize that it's detrimental, but is it baked in at all in your budgeting as you—you know, the fact that—it looks to me like budgeting in some ways is actually a reasonably stable but with this kind of crazy blip every two or three months where we say, well, we're going to shut down government for a weekend or whatever it may be. Is it baked in at all or can you elaborate on that I guess is what I'm trying to say?

Dr. PETERS. Well, given that it's, as you note, an annual occurrence, we understand how to manage through it, but I would never say that it's a good thing because it's the constant challenge to keep the staff excited and motivated when you're going through this, particularly—I'll also particularly note the early career staff who—some of us—we've been through this for a long time, but the early career staff watch this and they say why am I at a lab? Why don't I go work somewhere else? So it's a challenge. So the more we get the regular order and stable research funding, the better we can innovate.

Mr. BIGGS. Well, don't get me wrong; I'm not saying that that's the way to do it.

Dr. PETERS. Yes—

Mr. BIGGS. I'm all with you on a——

Dr. PETERS. Yes, I understand. But it does—but I'm just reacting to—

Mr. BIGGS. Yes.

Dr. PETERS. It's baked in in the sense that from the management perspective we know how to manage it, but that doesn't mean that the staff—

Mr. BIGGS. Fair enough.

Dr. PETERS. —don't get put through a lot of churn.

Mr. BIGGS. Yes.

Dr. SEESTROM. But I would say we're all used to, after 30 years, seeing continuing resolutions for a month or two, but the length that we're going now is really hard to deal with. Programs begin to lose funding and it's particularly hard on new starting projects—

Mr. BIGGS. Sure.

Dr. SEESTROM. —which can't get going in a CR.

Mr. BIGGS. We did one from December 8 to December 22 this year. How idiotic—I mean last year. Anyway, sorry. Dr. Kearns?

Dr. KEARNS. Yes, I was going to comment as well. I think a couple of things—and one is it is particularly difficult for early career scientists because it creates uncertainty, and of course they have lots of opportunities to go other places, as has already been mentioned by the panel. I think it's critical that during this time of uncertainty that the Laboratory Directors need to show some leadership and really step out front and talk about it being a process and also share our experience in terms of positive outcomes.

I would also say, though, it really is, as has just been commented by Susan in terms of impact on new starts or construction activities—or perhaps not a new start but where a ramp-up in funding is really planned for an ongoing project is particularly critical. You know, certainly, the Advanced Photon Source at Argonne has suffered this time and time again, and so we're really, you know, pleased with the indications of the fiscal year 2018 budget and hopefully the fiscal year 2019 budget will show a different story.

But really, it creates a lag. It takes away sense of urgency. It really kind of—really challenges us to really stay at the edge in terms of our thinking, so it's important that we're able to move forward.

Mr. BIGGS. Yes, and I will just tell you I'll keep pushing for us to do an annual budget so everybody can be more stable and more predictable. So, again, thank you for being here. Thank you, Mr. Chairman.

Mr. WEBER. Mr. Norman, you are up.

Mr. NORMAN. I just echo what Congressman Biggs says about the CRs where you can't run your business on a month-to-month basis, nor should we expect you. Thank each of you for your testimony.

Dr. Peters, in your prepared testimony, you talk about the work that the Idaho National Lab is doing to support the existing light-water reactor fleet like developing the new accident-resistant fuels are working with utilities to modernize nuclear power plant control rooms. What other research is the lab undertaking to help nuclear energy technology remain competitive?

Dr. PETERS. In the light-water reactor area, we're also working on materials so—because when the—when a utility want to take a reactor from 20 to 40 to 60 or even 80 years of operation, we need to ensure that the materials will survive that long. We see no showstoppers there, so every—all indications are that they'll be fine.

In the advanced reactor area where we're working with a lot of companies in partnership to help them mature their designs, make them more cost-competitive, everything from the reactor core itself to the fuel. We do extensive work on fuel development. So you mentioned accident-tolerant fuels that would go into light-water reactors but also developing advanced fuels for advanced reactors.

We're working a lot—we haven't talked a lot about it today, a lot on the nuclear fuel cycle, so we're—as you know, we're pursuing going to a repository now, but could there be options for reprocessing in the future? We're doing a lot of research in that area as well.

But I want to stress, you know, we're an applied laboratory, so we work very closely with industry across the whole gambit, and that's an important part of our focus.

Mr. NORMAN. Related to that, Dr. Peters, is there a direct benefit to the Department—to DOE, Department of Energy, to have the labs perform multidisciplinary science research for different programs across the Department? As an example, how does it benefit the Office of Science or NNSA to have the respective labs engage in diverse research for other DOE programs or federal agencies?

Dr. PETERS. We all have very—we all have unique capabilities, so I very much think that, for example, Sandia or Argonne is two good examples have capabilities that they've built in either the security or the basic science area that are very applicable to the applied programs. We partner very, very effectively. If you look at the capabilities at the 17 labs, some would argue you see duplication. I actually see a lot of complementarity, so there's tremendous opportunity.

And we're an applied nuclear lab, and we do a lot of work in the national security space and cybersecurity and whatnot because we have capability that can solve national problems. So collaboration is really important across the system, and I think it's quite effective actually.

Mr. NORMAN. It makes sense. Dr. Seestrom, as a nuclear weapons lab, Sandia has a specific mission to accomplish for DOE, but from your testimony, it sounds like the impact of Sandia's research has been much more broad. Can you provide some examples of areas of research that Sandia conducts for its nuclear weapons mission but that has also led to benefits in the civilian economy?

Dr. SEESTROM. So, you know, Sandia has expertise in hydrogen materials coming from our mission in NNSA for gas bottles. That leads us to certain expertise in chemical processes. In our Combustion Research Facility, we do research with each of the major U.S. car companies looking at improving fuel efficiency for light-duty and heavy-duty trucks as an example. You know, we have thousands of CRADAs there.

Our work for NNSA where we are responsible for radars have led to other national security work where, for the DOD, we've developed a next generation of synthetic-aperture radar, which lets us save our troops on the battleground with much better visibility through clouds that comes back to impact our core national security mission.

Mr. NORMAN. What about manufacturing?

Dr. SEESTROM. I don't think I can answer on manufacturing, but I'll take that for the record.

Mr. NORMAN. Okay. Thank you. I yield back.

Mr. WEBER. I thank the witnesses for their testimony and the Members for their questions. The record will remain open for two weeks for additional written comments and written questions from Members. This hearing is adjourned.

[Whereupon, at 12:05 p.m., the Committee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Mark Peters

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"National Laboratories: World-Leading Innovation in Science"

Dr. Mark Peters, Director, Idaho National Laboratory

Questions submitted by Rep. Daniel Lipinski, Ranking Member, Subcommittee on Research and Technology

1. **There is a misperception that the private sector will simply fund technologies when they reach a certain technology readiness level or when they have a clear application. But this ignores the realities of the market for new energy technologies and the way private capital decisions are actually made.**

    a) **What does it mean to de-risk technologies? What is the government role in funding research and working with industry to de-risk technologies?**

    b) **Could any of you comment on how the private sector views risk when it comes to technologies? Is it as simple as the technology readiness level (TRL)? If a technology is not at a certain TRL, but is beyond what many would consider "early-stage" research could there still be a worthy case for federal investments?**

As director of Idaho National Laboratory, I'm most familiar with nuclear energy research, development and deployment. By its very nature, nuclear energy has unique issues relating to the federal government role, specifically long durations for development and deployment, nonproliferation, waste disposition, and safety that require the involvement of the federal government. As a result of these and other issues, there is an important government role throughout the entire nuclear RD&D process.

As we work to deploy new technologies – next-generation reactors and advanced fuels that reduce cost and broaden the use of nuclear energy – private-public partnerships are essential, especially when it concerns the deployment of first-of-its-kind technologies.

The NuScale Power small modular reactor is an excellent example of this public-private partnership. Getting this reactor into the marketplace will help the Utah Associated Municipal Power Systems (UAMPS) meet customer demand for clean and reliable electricity in six Western states. It could also create technology leadership and favorable export opportunities for U.S. companies.

The federal government's assistance has been vital to the NuScale project, in the form of cost-sharing development of a license application to the Nuclear Regulatory Commission, access to INL researchers and facilities, potential siting at INL, and potential use of nuclear energy tax credits. Tax policy changes implemented at the state level will also help NuScale and UAMPS in their effort to deploy this first-of-its-kind reactor on the INL Site.

2. **While the Administration does not seem to see the value in engaging with the private sector before proposing major cuts to federal R&D programs, it does seem like a productive conversation to have regardless of this budget request.**

   a) **Could one of you discuss how the labs engage with the private sector to inform your research priorities or emerging opportunities?**

   b) **Would any of you have a suggestion for how the Department could better engage the private sector in a more formal process as they write next year's budget proposal?**

The Electric Power Research Institute (EPRI) is part of the Battelle Energy Alliance management team overseeing INL. EPRI represents roughly 1,000 organizations, primarily electric utilities, in more than 35 countries.

Through EPRI, INL stays in touch with the needs of private-sector utilities, businesses, and others involved in the generation, delivery, or use of electricity.

INL also is the lead laboratory in the Department of Energy's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative. Through GAIN, private-sector companies gain access to state-of-the-art infrastructure and expertise at the DOE national laboratories. Giving the private sector access to the technical, regulatory, and financial support available at the laboratories helps move new nuclear technologies toward the marketplace faster and more cost-effectively while supporting the continued operation and extending the lives of the nation's current reactor fleet.

GAIN often solicits industry stakeholder feedback through face-to-face meetings, workshops, and electronic surveys. This feedback informs research priorities and helps identify new programmatic opportunities for federally-funded programs.

Finally, the NuScale collaboration may continue even after the reactor begins producing power for UAMPS in 2026.

The Joint Use Modular Plant (JUMP) program would allow INL to use one or two of the reactor modules to demonstrate other energy processes, such as thermal energy storage and hydrogen production. Working with our industry partners, INL will examine how we can use energy differently in the future, and create more integrated energy systems.

Also, through JUMP, we would demonstrate safe, secure and resilient microgrid systems.

3. **Our national labs are not just used for DOE sponsored work. As some of you have noted, the labs play an important role in convening experts and stakeholders across disciplines and even federal agencies.**

   a) **How important is the work of the labs to convene scientific and technological expertise and create a nexus for federal agencies to solve common problems?**

   b) **Do any of you have good examples of this work at your labs?**

INL has an important leadership role in protecting the electric grid and control systems more broadly from cyberattack. In this role, INL helps organize government agencies and private utilities to develop strategies and technologies to combat the cyberthreat to the grid. INL also organizes cyber training for the private sector, government agencies, Department of Defense, and DOE.

An example of this is INL's Cybersecurity 301 Course, better known as Red-Blue Training. This exercise is funded by the Department of Homeland Security, supported by INL personnel and provided to universities, utilities, regulators, and federal partners.

As the nation's lead nuclear energy R&D laboratory, INL is also a leader in providing technological expertise and helping solve complex issues related to the existing reactor fleet and the effort to demonstrate and deploy the next generation of nuclear reactors.

Working through programs such as the Accident Tolerant Fuel program and the Light Water Reactor Sustainability program, researchers from INL and other labs work with industry to tackle technical issues that require the distinctive capabilities of the national laboratory system to support improved operations, safety, and economic performance. These cost-shared programs make use of national laboratory capabilities to serve the public interest.

4. **We have heard from scientists and policymakers alike that there is often a false boundary drawn between basic and applied science. To some, supporting "basic research" is an important role of government while "applied research" should be left to the private sector. Yet this idea that there is a line that neatly divides two separate levels of research is not realistic and certainly goes against our general understanding of scientific discovery and innovation.**

   a) **Would you agree with this characterization?**

   b) **How can we dispel this myth and ensure it is not perpetuated in the upcoming budget request?**

I believe there is a vital federal government role across the entire RD&D spectrum. The 17 DOE laboratories possess unique capabilities, operate as a system, complement each other well, and are the envy of the world.

Other nations, including China, are seeking to replicate what we have. Through our example, they have come to understand how federal government investment in R&D leads to prosperity and industry competiveness.

Some DOE labs focus on fundamental science and that must continue because we can never stop innovating. Other labs, such as INL, focus on direct impact, developing and testing technologies in preparation for the marketplace. One of our highest priorities must be continuing to do a better job as a laboratory system in working together, because that's how we move the needle on energy and security innovation.

5. **The Office of Science was flat funded in the budget request, but there were harmful cuts to important research within the Office of Science. The Biological and Environmental Research program (BER) would be cut by 18%. Many would probably not be surprised to learn that BER is the largest sponsor of climate change-related research at DOE.**

    a) **Should we be fully funding the activities within Earth and Environmental Systems Sciences?**

    b) **For those in the Administration that think climate change is unsettled science, wouldn't it make sense then to further invest in the research to give us a clearer answer on the state of our climate?**

Idaho National Laboratory does not receive significant funding from the Office of Science. Because INL does not do extensive work in this area, I haven't closely studied this program or the impact of potential budget cuts.

6. **The common argument we often hear is that we should cut some R&D programs because those activities it is more appropriate for them to be carried out by the private sector. But in reality, private sector R&D spending is actually driven by federal investment. The American Association for the Advancement of Science found that when federal R&D is increased, the private sector responds not by decreasing their R&D funding – so-called crowding out – but rather by increasing R&D spending in response, thus multiplying that one dollar spent by the government by sometimes three or four.**

    a) **Have your labs witnessed this multiplier effect in federal R&D investments, or do you believe that federal R&D investments crowd out private investment?**
        i) **Why wouldn't the private sector increase R&D spending as a result of federal spending cuts? Why is private R&D so closely correlated with federal R&D investments?**

In my experience, federal RD&D spending leveraged by private-sector investments creates excellent energy and security science and technology outcomes. An example of meaningful and successful private-public partnership is the Office of Nuclear Energy's Light Water Reactor Sustainability program.

The LWRS program is funded through a 50/50 public-private split, with the intention of meeting nuclear plant needs for the benefit of industry and the American taxpayer. This effort has helped extend the lives of several nuclear power plants. Also, the program has evolved from one concerned primarily with licensing to an effort to help the private sector improve the economics of their operations.

Now, the LWRS program is evolving again, to help plant operators focus on more than just electricity generation. INL, the National Renewable Energy Lab and others are now looking at integrated energy systems to assess how nuclear power plants can increase their profitability by using their process heat and energy storage options to maintain operations when intermittent renewable energy systems make the production of electricity unnecessary and to impact markets beyond electricity production, in particular, the transportation and manufacturing sectors.

Responses by Dr. Susan Seestrom

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"National Laboratories: World-Leading Innovation in Science"

Dr. Susan Seestrom, Advanced Science and Technology Associate Laboratory Director and Chief Research Officer, Sandia National Laboratory

Questions submitted by Rep. Daniel Lipinski, Ranking Member, Subcommittee on Research and Technology

1. **There is a misperception that the private sector will simply fund technologies when they reach a certain technology readiness level or when they have a clear application. But this ignores the realities of the market for new energy technologies and the way private capital decisions are actually made.**

   a) **What does it mean to de-risk technologies? What is the government role in funding research and working with industry to de-risk technologies?**

As a national security laboratory Sandia does not have the expertise to speak to the issue of de-risking energy technologies for industry. We develop technologies to serve national security, and risk tolerance is very different in that sector.

   b) **Could any of you comment on how the private sector views risk when it comes to technologies? Is it as simple as the technology readiness level (TRL)? If a technology is not at a certain TRL, but is beyond what many would consider "early-stage" research could there still be a worthy case for federal investments?**

We have no insights to offer on the views of industry.

2. **While the Administration does not seem to see the value in engaging with the private sector before proposing major cuts to federal R&D programs, it does seem like a productive conversation to have regardless of this budget request.**

   a) **Could one of you discuss how the labs engage with the private sector to inform your research priorities or emerging opportunities?**

Sandia's research priorities are largely driven by our government national security sponsors. However, we do include representatives from industry and academia on many of our external advisory boards so as to maintain two-way communications with those important communities.

   b) **Would any of you have a suggestion for how the Department could better engage the private sector in a more formal process as they write next year's budget proposal?**

No.

3. **Our national labs are not just used for DOE sponsored work. As some of you have noted, the labs play an important role in convening experts and stakeholders across disciplines and even federal agencies.**

   a) **How important is the work of the labs to convene scientific and technological expertise and create a nexus for federal agencies to solve common problems?**

It is essential, especially in a period of constrained budgets.

   b) **Do any of you have good examples of this work at your labs?**

We led a team of experts from several national labs and industries during the Deepwater Horizon incident.

4. **We have heard from scientists and policymakers alike that there is often a false boundary drawn between basic and applied science. To some, supporting "basic research" is an important role of government while "applied research" should be left to the private sector. Yet this idea that there is a line that neatly divides two separate levels of research is not realistic and certainly goes against our general understanding of scientific discovery and innovation.**

   a) **Would you agree with this characterization?**

As a national security lab, Sandia does research that covers the spectrum from basic through use-inspired to applied research. In the case of our mission this applied research cannot be left to industry.

   b) **How can we dispel this myth and ensure it is not perpetuated in the upcoming budget request?**

We have no insights to provide.

5. **The Office of Science was flat funded in the budget request, but there were harmful cuts to important research within the Office of Science. The Biological and Environmental Research program (BER) would be cut by 18%. Many would probably not be surprised to learn that BER is the largest sponsor of climate change-related research at DOE.**

   a) **Should we be fully funding the activities within Earth and Environmental Systems Sciences?**

The work of the Office of Science is important as the major funder of the physical sciences in the country. We support the Department in making the best decisions they can on programs within the budget allocated to them.

b) For those in the Administration that think climate change is unsettled science, wouldn't it make sense then to further invest in the research to give us a clearer answer on the state of our climate?

We have no insights to provide.

6. The common argument we often hear is that we should cut some R&D programs because those activities it is more appropriate for them to be carried out by the private sector. But in reality, private sector R&D spending is actually driven by federal investment. The American Association for the Advancement of Science found that when federal R&D is increased, the private sector responds not by decreasing their R&D funding – so-called crowding out – but rather by increasing R&D spending in response, thus multiplying that one dollar spent by the government by sometimes three or four.

a) Have your labs witnessed this multiplier effect in federal R&D investments, or do you believe that federal R&D investments crowd out private investment?

As a national security laboratory there is not much overlap between the research we engage in and that which could potentially be undertaken by private industry. We have seen cases in which industry as invested in advancing technologies we have developed for their purposes, and this has improved those technologies for our use.

i) Why wouldn't the private sector increase R&D spending as a result of federal spending cuts? Why is private R&D so closely correlated with federal R&D investments?

We have no insights to provide.

Responses by Dr. Mary E. Maxon

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"National Laboratories: World-Leading Innovation in Science"

Dr. Mary E. Maxon, Associate Laboratory Director for Biosciences, Lawrence Berkeley National Laboratory

Questions submitted by Rep. Daniel Lipinski, Ranking Member, Subcommittee on Research and Technology

1. **There is a misperception that the private sector will simply fund technologies when they reach a certain technology readiness level or when they have a clear application. But this ignores the realities of the market for new energy technologies and the way private capital decisions are actually made.**

    a) **What does it mean to de-risk technologies? What is the government role in funding research and working with industry to de-risk technologies?**

De-risk = decrease or remove the risk (financial and/or technological) from the technology development project. This can be done through identifying and addressing shared pre-competitive challenges that have elements of basic and/or use-inspired research and development. Another way to de-risk technologies is to address shared challenges that would result in improvements in practices but for which there is not a private sector business motivation to do so.

The government can (1) convene stakeholders to identify shared challenges, and (2) can provide incentives, such as funding and vouchers, to address those challenges and require that the solutions are made known in the public literature

    b) **Could any of you comment on how the private sector views risk when it comes to technologies? Is it as simple as the technology readiness level (TRL)? If a technology is not at a certain TRL, but is beyond what many would consider "early-stage" research could there still be a worthy case for federal investments?**

From my experience in the biotechnology sector, TRL is not a common term nor a common way to view technology maturity. I never heard that term in any of the three companies in which I worked.

As a technology advances through the "levels", it does not mean that risks have been eliminated; risk exists within at all stages of development.

Often, even at the "higher" TRL levels, there are basic science questions with broad applicability beyond that specific technology that once answered, will have a much wider range of impact, arguing that federal investments would be warranted to broadly accelerate innovation.

2. **While the Administration does not seem to see the value in engaging with the private sector before proposing major cuts to federal R&D programs, it does seem like a productive conversation to have regardless of this budget request.**

   a) **Could one of you discuss how the labs engage with the private sector to inform your research priorities or emerging opportunities?**

Berkeley Lab began holding industry listening days in 2013 after the release of its Biosciences Strategic Plan, specifically to identify shared industry challenges associated with biomanufacturing. Today, Berkeley Lab engages in a variety of industry engagement activities with and without other national labs to inform research priorities and emerging opportunities for greater impact.

As integrators of research funding and resources, all national laboratories engage industry on a consistent and often deep level. From working with industry to leverage national scientific user facilities (such as the ALS and FLEXLab at Berkeley Lab), to entering into CRADAs and other industry funded R&D relationships, labs are often an important component of a company's R&D enterprise. One great example is Berkeley Lab's relationship with CalCharge, a coalition of California based battery companies that signed a CRADA under which its member companies can engage the Lab in research projects. This relationship speeds the development of science and technology.

Finally, research programs, such as the DOE Bioenergy Centers (JBEI at Berkeley Lab), often stand up industry advisory committees and engage industry partners in important research that leverages the federal investment.

   b) **Would any of you have a suggestion for how the Department could better engage the private sector in a more formal process as they write next year's budget proposal?**

The Department could (1) convene relevant industry representatives to solicit input, (2) develop a Request for Information (RFI) for relevant industry sectors and partner with industry trade groups to disseminate the RFI.

3. **Our national labs are not just used for DOE sponsored work. As some of you have noted, the labs play an important role in convening experts and stakeholders across disciplines and even federal agencies.**

   a) **How important is the work of the labs to convene scientific and technological expertise and create a nexus for federal agencies to solve common problems?**

Critically important. National labs have core capabilities on which the nation depends. The assembled technical expertise at the national labs is unparalleled, and many countries are attempting now to build own versions modeled after ours.

b) Do any of you have good examples of this work at your labs?

As mentioned, Berkeley Lab convened biomanufacturing workshops with industry representatives in 2013, 2015 and 2016.

The EERE funded Agile BioFoundry (and other BETO consortia) continually consult industry advisory boards to learn about and better understand critical challenges, as well as solicit information about key externalities that could impact project success.

4. We have heard from scientists and policymakers alike that there is often a false boundary drawn between basic and applied science. To some, supporting "basic research" is an important role of government while "applied research" should be left to the private sector. Yet this idea that there is a line that neatly divides two separate levels of research is not realistic and certainly goes against our general understanding of scientific discovery and innovation.

a) Would you agree with this characterization?

b) How can we dispel this myth and ensure it is not perpetuated in the upcoming budget request?

In my oral testimony I stated that there is no bright line; rather it is a continuum. It is common for scientific advances to give rise to new information and new questions of various levels that feed "backwards" and "forwards" along the continuum.

5. The Office of Science was flat funded in the budget request, but there were harmful cuts to important research within the Office of Science. The Biological and Environmental Research program (BER) would be cut by 18%. Many would probably not be surprised to learn that BER is the largest sponsor of climate change-related research at DOE.

a) Should we be fully funding the activities within Earth and Environmental Systems Sciences?

b) For those in the Administration that think climate change is unsettled science, wouldn't it make sense then to further invest in the research to give us a clearer answer on the state of our climate?

Yes. Funding Earth and Environmental Sciences provides critical information about the very elements required for biological life: carbon, nitrogen, phosphorus. We need these studies to help understand the biogeochemical cycles that drive terrestrial and atmospheric cycles of life on Earth, to help us understand environmental resiliency, and to predict and respond to extreme events such as hurricanes and flooding.

6. The common argument we often hear is that we should cut some R&D programs because those activities it is more appropriate for them to be carried out by the private sector. But in reality, private sector R&D spending is actually driven by federal investment. The American Association for the Advancement of Science found that when federal R&D is increased, the private sector responds not by decreasing their R&D funding – so-called crowding out – but rather by increasing R&D spending in response, thus multiplying that one dollar spent by the government by sometimes three or four.

a) Have your labs witnessed this multiplier effect in federal R&D investments, or do you believe that federal R&D investments crowd out private investment?

i) Why wouldn't the private sector increase R&D spending as a result of federal spending cuts? Why is private R&D so closely correlated with federal R&D investments?

Industry research objectives are not perfectly overlapping with those of the national labs, nor can industry perform some of the work that requires national lab core capabilities/user and collaboration facilities, so decreases in federal funding would not be expected to translate to increases on the private side.

Industry investments track federal investments as a function of decreased uncertainty; if industry is certain that federal investments are being made, there is confidence to also invest, a positive feedback loop. For example, the establishment of the National Nanotechnology Initiative gave confidence to industry that the federal government was prepared to serious invest in strategic and coordinated ways in nanotechnology research.

Responses by Dr. Chi-Chang Kao

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"National Laboratories: World-Leading Innovation in Science"

Dr. Chi-Chang Kao, Director, Stanford Linear Accelerator Center, National Accelerator Laboratory

Questions submitted by Rep. Daniel Lipinski, Ranking Member, Subcommittee on Research and Technology

1. **There is a misperception that the private sector will simply fund technologies when they reach a certain technology readiness level or when they have a clear application. But this ignores the realities of the market for new energy technologies and the way private capital decisions are actually made.**

   a) **What does it mean to de-risk technologies? What is the government role in funding research and working with industry to de-risk technologies?**

   b) **Could any of you comment on how the private sector views risk when it comes to technologies? Is it as simple as the technology readiness level (TRL)? If a technology is not at a certain TRL, but is beyond what many would consider "early-stage" research could there still be a worthy case for federal investments?**

Some industries are slow to change their business-as-usual strategies when it comes to developing, investing in and rapidly adopting disruptive technologies because this can require large, sustained investments in facilities and infrastructure and significant changes in their workforce. To succeed in the marketplace, the innovation must work as advertised and demonstrate value that exceeds its cost and differentiates it from competing products. Failure can mean significant loss of money, time and effort.

The government can play an important role in decreasing the risks that industry takes when exploring new technologies. For instance, SLAC and other labs in the DOE complex give industry access to unique tools and expertise needed to test out innovations, and they provide unbiased benchmarking across different technologies and approaches, greatly reducing risks. Research conducted at the labs in partnership with industry can help speed the process of discovery and the transition from conceptual ideas to technologies and applications with real impact.

2. **While the Administration does not seem to see the value in engaging with the private sector before proposing major cuts to federal R&D programs, it does seem like a productive conversation to have regardless of this budget request.**

   a) **Could one of you discuss how the labs engage with the private sector to inform your research priorities or emerging opportunities?**

   b) **Would any of you have a suggestion for how the Department could better engage the private sector in a more formal process as they write next year's budget proposal?**

Research priorities at the national labs are largely driven by a need to address critical national challenges, solve difficult technological problems and pursue scientific curiosity. The private sector is generally interested in solutions that can be commercialized on a much shorter timescale.

That said, there are situations when the private sector's interest aligns well with a lab's strategic direction. We are seeing this today in a partnership with the telecommunications industry where there is a focus on longer-term, high-payoff technologies and an appreciation for SLAC's unique capabilities and expertise. In this partnership, SLAC is working to develop advanced millimeter-wave radiofrequency (RF) technology for future high-bandwidth 5G communications. Leveraging core capabilities in accelerator science and technology, SLAC brings to the collaboration a combination of expertise in electrodynamics and supercomputer-based computational tools that does not exist elsewhere.

Other successful engagements with the private sector have come from partnerships made possible through efforts like the DOE's Accelerator Stewardship Program, where industry and the federal labs partner on a DOE-funded project in which the industrial partner also makes an investment. Thus far, these efforts have been narrow in scope, and extending them into a broader variety of topic areas could benefit both industry and the labs.

3. **Our national labs are not just used for DOE sponsored work. As some of you have noted, the labs play an important role in convening experts and stakeholders across disciplines and even federal agencies.**

   a) **How important is the work of the labs to convene scientific and technological expertise and create a nexus for federal agencies to solve common problems?**

   b) **Do any of you have good examples of this work at your labs?**

The national labs are primary drivers for scientific discovery and innovation, central to the U.S. and international scientific communities. The expertise found across the labs gives federal agencies sound, unbiased scientific and technical advice to assist them in carrying out their missions. The difficult problems and challenges faced by these agencies often require a multidisciplinary perspective, which is readily available across the labs.

The unique core capabilities available in DOE laboratories include scientific and technical expertise in the design, construction and operation of advanced accelerators and instrumentation, which are often on a scale too large to realize in the typical university or industry setting. The laboratories also have significant resources and R&D programs in advanced computation and "big data" handling. In addition, they have decades of experience in operating large, complex national user facilities effectively and efficiently.

This integrated set of capabilities supports the research mission needs of other Federal agencies. For instance, synchrotron X-rays from the DOE's light sources serve thousands of scientists doing NIH-sponsored research in the biomedical sciences – studies that lead to novel therapeutics and vaccines and inform applications in synthetic biology, microbiome and biomaterials research, regenerative medicine, production of biofuels and bioremediation of environmental contaminants.

Advanced RF accelerator technology has been applied across a range of agencies, including DOE/NNSA, the DHS/DNDO and DARPA. These agencies have similar goals for using this technology to develop tools for finding and analyzing illicit nuclear materials. Similar technologies are being pursued at SLAC to revolutionize the field of radiation oncology, with the longer-term goal of addressing the difficulty of providing accessible and affordable cancer treatment in developing countries.

The DoD and the intelligence community have a number of other needs in the areas of remote sensing, signal detection, directed energy and radar where lab technologies can play a pivotal role. The Strategic Defense Initiative in the 1980s and 1990s led to critical R&D at the labs on free-electron lasers and neutral particle beam accelerators. In addition to the national security role they played at the time, these efforts laid the science and technology foundation for the LCLS and LCLS-II X-ray free-electron lasers at SLAC. The labs continue to bring their technologies to bear on problems of national interest in their work with organizations across the DoD, DARPA and the intelligence community.

In developing distribution grid technologies, SLAC has also convened a number of stakeholders to communicate the approaches we are taking, collecting use cases from utilities and working with industry to ensure the compatibility of solutions that we deliver.

4. **We have heard from scientists and policymakers alike that there is often a false boundary drawn between basic and applied science. To some, supporting "basic research" is an important role of government while "applied research" should be left to the private sector. Yet this idea that there is a line that neatly divides two separate levels of research is not realistic and certainly goes against our general understanding of scientific discovery and innovation.**

    a) **Would you agree with this characterization?**

    b) **How can we dispel this myth and ensure it is not perpetuated in the upcoming budget request?**

Research at the national labs supports discoveries across the spectrum of fundamental to applied science. While basic science may focus on fundamental discovery and understanding, this knowledge underpins the application of new insights into practical and value-creating technologies. Connecting application knowledge to basic science, often referred to as "use-inspired" research, can help highlight opportunities that could have significant impact, while providing relevant context to bind the open-ended discovery process. Continuing to discuss and promote the work happening across this continuum can highlight the value of the labs to innovation at every stage.

5. **The Office of Science was flat funded in the budget request, but there were harmful cuts to important research within the Office of Science. The Biological and Environmental Research program (BER) would be cut by 18%. Many would probably not be surprised to learn that BER is the largest sponsor of climate change-related research at DOE.**

    a) **Should we be fully funding the activities within Earth and Environmental Systems Sciences?**

    b) **For those in the Administration that think climate change is unsettled science, wouldn't it make sense then to further invest in the research to give us a clearer answer on the state of our climate?**

SLAC receives funding from the Biological and Environmental Research (BER) program for work in structural molecular biology, waste remediation studies and subsurface research. Though the laboratory does not have a climate science program, we support continued investments in BER funding for advancing important science underway across the laboratories.

6. **The common argument we often hear is that we should cut some R&D programs because those activities it is more appropriate for them to be carried out by the private sector. But in reality, private sector R&D spending is actually driven by federal investment. The American Association for the Advancement of Science found that when federal R&D is increased, the private sector responds not by decreasing their R&D funding – so-called crowding out – but rather by increasing R&D spending in response, thus multiplying that one dollar spent by the government by sometimes three or four.**

    a) **Have your labs witnessed this multiplier effect in federal R&D investments, or do you believe that federal R&D investments crowd out private investment?**
        i) **Why wouldn't the private sector increase R&D spending as a result of federal spending cuts? Why is private R&D so closely correlated with federal R&D investments?**

Federal and private R&D focus on different areas and stages of science and technology; they are both essential to progress. National labs play a critical and irreplaceable role as the builders and operators of large-scale facilities that provide multiple, advanced scientific tools available to a variety of industry partners. These facilities, such as SLAC's X-ray laser or synchrotron light source, could not be built without federal investment. They also attract top scientists and researchers to the national labs who drive research and industry collaboration; our work with Stanford University is a case in point.

These tools and collaborations lead to discoveries that provide fundamental strategies for industry to pursue. Stanford's Roger Kornberg conducted his Nobel Prize-winning research at SLAC's synchrotron, SSRL, and made RNA polymerase a focus of pharmaceutical strategies in drug design and development that have been of tremendous benefit to human health. Similarly, materials science studies underway at the labs are instrumental in the development of future electronics and are the basis for new concepts being applied by companies working to revolutionize energy storage and information storage, among other applications.

Responses by Dr. Paul Kearns

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"National Laboratories: World-Leading Innovation in Science"

Dr. Paul Kearns, Director, Argonne National Laboratory

Questions submitted by Rep. Daniel Lipinski, Ranking Member, Subcommittee on Research and Technology

1. **There is a misperception that the private sector will simply fund technologies when they reach a certain technology readiness level or when they have a clear application. But this ignores the realities of the market for new energy technologies and the way private capital decisions are actually made.**

   a) **What does it mean to de-risk technologies? What is the government role in funding research and working with industry to de-risk technologies?**

   b) **Could any of you comment on how the private sector views risk when it comes to technologies? Is it as simple as the technology readiness level (TRL)? If a technology is not at a certain TRL, but is beyond what many would consider "early-stage" research could there still be a worthy case for federal investments?**

De-risking is the process of reducing elements of risk (technical risks, market risks, etc.) throughout the development of a technology. Such risks can be obstacles to commercialization. New technologies, especially those substantially different from existing technologies, tend to require a long incubation period before they reach the performance level and cost needed to replace an incumbent technology.

For example, history shows us that moving innovative batteries from the lab to the market can take 10 to 20 years. Raising the kind of capital needed—potentially hundreds of millions of dollars—to ensure mass manufacturing requires that investors see a certain maturity in the technology. De-risking involves moving the technology through various developmental stages to reach this level of maturity.

National laboratories have existing and complementary relationships with industry that bring exemplary science and facilities to bear in helping meet the de-risking challenge. For instance, in its Materials Engineering Research Facility, Argonne scales up materials—such as those used in batteries and fuel cells—from the milligram level to the kilogram level. This enables researchers to examine the costs and challenges associated with scale-up and ultimately provide manufacturers the formula for an industrial, commercial process.

The role of government labs in de-risking technologies is to promote scientific understanding and demonstrate technical feasibility. Industry's role is to capture economic opportunities that deliver desired products and services.

The private sector would be best positioned to provide its perspective on risk; we can offer the laboratories' perspective based on our numerous and longstanding industry relationships. The labs and industry view research as a continuum from basic, curiosity-driven efforts, to use-inspired science solving problems of global significance, to translation science in order to deliver meaningful societal impact consistent with our mission. This approach, in contrast to a strictly "readiness-level" construct, enables us to accelerate scientific progress from discovery to impact.

Laboratories work to accelerate that discovery-to-impact process by helping researchers execute experiments and simulations more quickly. For example, national labs are applying the latest high-throughput methods for analytical characterization, as well as innovations like deep learning, machine learning, and artificial intelligence to transform processes that previously took decades so that they now require only a fraction of that time. Such achievements make a worthy case for federal investment.

2. **While the Administration does not seem to see the value in engaging with the private sector before proposing major cuts to federal R&D programs, it does seem like a productive conversation to have regardless of this budget request.**

    a) **Could one of you discuss how the labs engage with the private sector to inform your research priorities or emerging opportunities?**

    b) **Would any of you have a suggestion for how the Department could better engage the private sector in a more formal process as they write next year's budget proposal?**

Working with industry informs the national laboratories about practical solutions, enables our scientists and engineers to work with more market relevance in the national labs' core mission, and provides us more avenues to create impact from translating our science to societal benefits. Argonne engages with the private sector in numerous ways. The Joint Center for Energy Research (JCESR), scientific user facilities like the Advanced Photon Source (APS) and the Argonne Leadership Computing Facility (ALCF), and Cooperative Research and Development Agreements (CRADAs) all demonstrate how Argonne researchers connect with private-sector counterparts and share national resources to identify new research priorities and address emerging opportunities.

JCESR, the Department of Energy's (DOE's) battery and energy storage hub, has changed the formula for developing next-generation batteries. Experiments with new battery chemistries have resulted in the discovery of revolutionary new materials that scientists use to develop beyond-lithium-ion technologies. The JCESR operations model, meanwhile, has integrated and amplified the effectiveness of 20 otherwise independent interdisciplinary scientific organizations—including universities, industry, and national laboratories—as a single coordinated unit. This new paradigm for public-private partnership has enabled more than 200 researchers to magnify their efforts and achievements in discovery science, materials design, battery design, research prototyping, and manufacturing.

At the APS, more than 200 companies have research agreements to use the facility's hard X-rays to examine materials at the atomic level to propel progress in science, medicine and technology. For example, Kaletra®, one of the most successful drugs used to stop the progression of HIV into AIDS, started at the APS; visiting scientists from Abbott Laboratories used X-ray crystallography to pinpoint how the atoms of the drug interact with the viral protein.

Through CRADAs, industrial partners can optimize research and development (R&D) funds by collaborating with the DOE—and even with one another—to share the results of jointly conducted R&D. Costs, personnel, facilities, equipment, and research capabilities are typically used on a cost-share basis. In one such example at Argonne, software developer Convergent Science, Inc., and heavy equipment manufacturers Caterpillar and Cummins collaborated with Argonne to access cutting-edge computer modeling, analysis tools, and expertise that allowed them to achieve major advances in fuel economy and reduce development costs and time-to-market for engines.

Argonne also brings together laboratory researchers and industry—as well as academic and entrepreneurial partners—at workshops to analyze challenges and solutions in particular sectors. Argonne's 2017 Battery Industry Day, for example, attracted more than 100 industry representatives who shared their research challenges and explored the laboratory's capabilities to address them. Laboratory representatives also attend conferences and trade shows where we present our science, listen to private sector presentations, and explore matters of shared interest. In addition, when lab researchers publish their science, they encourage engagement from the larger community of scientists, including those in the private sector.

The laboratories also continue to work with the DOE on a broad range of mechanisms to engage industry. One example is the Agreement for Commercializing Technology (ACT), which was developed to give DOE laboratories and facilities more flexibility in engaging with industry on research and technology transfer projects; the ACT provides terms and conditions that are more consistent with industry practice than those permitted under DOE's traditional research agreements.

In addition, the Chain Reaction Innovations program, funded through the DOE Office of Energy Efficiency & Renewable Energy/Advanced Manufacturing Office, enables Argonne to support competitively selected energy entrepreneurs for 2 years of research and development. Argonne provides entrepreneurs the laboratory resources they need to grow and attract the long-term capital and commercial partners they need to scale up their innovation and launch into the marketplace.

Argonne also participates in DOE's Executive in Residence Program, which enables company-employed scientists to work with laboratory senior technical staff during the later stages of technical development. Several DOE program offices also engage closely with academia, national labs, and industry to define domain-specific roadmaps for science and technology development as a basis for future funding activities.

The national labs are at their best when they are working as part of an innovation ecosystem with academic, industrial, and entrepreneurial partners. Argonne resides at the heart of a bustling industrial and rigorous academic region, surrounded by some of the world's largest companies and top-tier universities. In addition to our strong engagement with regional private sector partners, Argonne researchers also seek world-changing scientific discoveries and technological breakthroughs alongside colleagues from research institutions, including the University of Illinois at Urbana-Champaign, University of Illinois at Chicago, Northwestern University, the University of Chicago and others across the country.

Our collaboration is particularly strong with the University of Chicago, which manages and operates the laboratory for the DOE Office of Science through UChicago Argonne, LLC. Approximately 200 researchers have joint appointments with the University and Argonne, including within the Institute for Molecular Engineering, which translates discoveries in basic physics, chemistry, and biology into new tools to address important societal problems in areas including water and energy storage.

Another area of strong collaboration with the University is advancing quantum materials and quantum information science. Argonne and the University recently worked together to build "The Quantum Factory"— a comprehensive experimental facility for the synthesis of quantum materials with atomic layer precision. Additionally, the University and Argonne joined Fermi National Accelerator Laboratory, located in Batavia, Illinois, to launch on the Chicago Quantum Exchange, which serves as hub to coordinate and advance academic, industrial and government efforts in the science and engineering of quantum information. With access to state-of-the art facilities and leading experts from the National Laboratories and the University, CQE will also help train a new generation of quantum engineers and scientists to meet the future workforce demands.

3. **Our national labs are not just used for DOE sponsored work. As some of you have noted, the labs play an important role in convening experts and stakeholders across disciplines and even federal agencies.**

   a) **How important is the work of the labs to convene scientific and technological expertise and create a nexus for federal agencies to solve common problems?**

   b) **Do any of you have good examples of this work at your labs?**

The DOE and its laboratories are critically important in advancing projects—alone and in collaboration with other federal agencies—that will keep the United States at the forefront of science and innovation for decades to come. For example, the ALCF leads a multi-laboratory team as part of the federal Precision Medicine Initiative with the National Cancer Institute (NCI). Newly developed codes will address major challenges in determining optimal cancer treatment strategies, such as automating the analysis and extraction of information from millions of cancer patient records.

ALCF also plays a prominent role in the MVP-CHAMPION initiative, which brings the Department of Veterans Affairs (VA) together with the DOE to improve healthcare for our nation's veterans. This collaborative research effort pairs the laboratories' big data, artificial intelligence, and high-performance computing capabilities with the VA's vast healthcare and genomic data to improve health outcomes and reduce costs.

Argonne also developed the CyberFed Model (CFM), a community-based system to give the large, distributed national laboratory system the agility to defend against cyber threats. Through near-real-time dissemination of highly relevant and actionable cyber-threat intelligence, CFM proactively defends members from active attacks. CFM approaches machine-to-machine information sharing in a novel way that enables synchronized, global defense: members submit local threat intelligence to CFM's robust, distributed network. CFM then immediately disperses local threat intelligence to other members. As a result, this collective cyber-threat intelligence reduces the cost of defense to members and addresses the ever-changing risks posed by cyber-attacks.

Argonne is involved in other national collaborations including the National Nanotechnology Initiative, a government R&D initiative that coordinates the nanotechnology-related activities of 20 departments and independent agencies. Argonne also plays a major role in the Exascale Computing Project, a collaborative effort through which the DOE Office of Science and the National Nuclear Security Administration accelerate delivery of exascale computing to provide breakthrough modeling and simulation solutions that address the most critical challenges in scientific discovery, energy assurance, economic competitiveness, and national security.

4. **We have heard from scientists and policymakers alike that there is often a false boundary drawn between basic and applied science. To some, supporting "basic research" is an important role of government while "applied research" should be left to the private sector. Yet this idea that there is a line that neatly divides two separate levels of research is not realistic and certainly goes against our general understanding of scientific discovery and innovation.**

    a) **Would you agree with this characterization?**

    b) **How can we dispel this myth and ensure it is not perpetuated in the upcoming budget request?**

The laboratories view research on a continuum: fundamental science progresses to use-inspired science, which progresses to translational science, which in turn progresses to industrial use. In many cases, something that appears ready to move from one stage to another has to be reconsidered as we discover new and fundamental challenges that have not yet been solved. Drawing a bright line between these terms is difficult because they are closely related, and the entire continuum is necessary to create market impact.

The way in which national labs deploy our broad and deep domain knowledge and unique facilities across the scientific continuum distinguishes us as institutions. We accelerate scientific progress from discovery to impact. Through our existing and complementary relationships with industry and academia, which bring exemplary science and facilities to bear on a range of societal challenges, national labs provide value at all points of the science and technology development cycle. Labs not only seed the gradual growth of new ideas but also reverse engineer to stabilize and improve ideas as they emerge in the market.

5. **The Office of Science was flat funded in the budget request, but there were harmful cuts to important research within the Office of Science. The Biological and Environmental Research program (BER) would be cut by 18%. Many would probably not be surprised to learn that BER is the largest sponsor of climate change-related research at DOE.**

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The Biological and Environmental Research (BER) has embarked on developing the most advanced earth systems computer model targeting exascale computers. This advanced earth systems model will enable high-resolution studies of the impact of extreme weather on the global hydrological cycle, giving us deeper insights to future droughts, floods, wildfires, hurricanes and agriculture sustainability. These natural events impact millions of people each year and cost billions of dollars.

Understanding the climate system and determining knowledge gaps are critical. The national laboratories prioritize work with the DOE to research questions based on how they improve our understanding and predicative models.

6. **The common argument we often hear is that we should cut some R&D programs because those activities it is more appropriate for them to be carried out by the private sector. But in reality, private sector R&D spending is actually driven by federal investment. The American Association for the Advancement of Science found that when federal R&D is increased, the private sector responds not by decreasing their R&D funding – so-called crowding out – but rather by increasing R&D spending in response, thus multiplying that one dollar spent by the government by sometimes three or four.**

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        i) **Why wouldn't the private sector increase R&D spending as a result of federal spending cuts? Why is private R&D so closely correlated with federal R&D investments?**

R&D coordinated between government and industry is the engine that powers the U.S. economy and keeps us competitive. Government-funded R&D typically focuses on higher-risk, longer-term problems. As such, government-funded R&D serves as a foundation as well as a complement to industry R&D expenditures, which are typically focused on shorter-term, later-stage, and lower-risk efforts.

Federal investment in national laboratories also enables the labs to take a broad view in designing, building, and operating shared scientific user facilities that would not be cost effective for a single company or university to build and operate. An excellent example of the "multiplier" effect—and the laboratories' approach to forming complementary relationships with industry and bringing exemplary science and facilities to bear on societal challenges—exists at Argonne's APS. The Industrial Macromolecular Crystallography Association Collaborative Access Team (IMCA-CAT), an association of pharmaceutical companies committed to the use of macromolecular crystallography as a tool in drug discovery and product development, established the IMCA-CAT sector at the APS. Research conducted at the IMCA-CAT led to the development of a GlaxoSmithKline pharmaceutical, Votrient®, which combats two deadly forms of cancer: soft-tissue sarcoma and kidney cancer.